Spring 5-19-1968

The Geology of the White Oaks-Patos Mountain Area, Lincoln County, New Mexico

Richard A. Haines

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of The University of New Mexico in partial fulfillment of the requirements for the degree of Master of Science

Geology of the White Oaks - Patos
Mountains Area, Lincoln County, New Mexico
Title

Richard A. Haines
Candidate

Geology
Department

A. L. Stege
Dean

5-29-68
Date

Committee

Vincent C. Kelley
Chairman

Lee A. Woodward

Wolfgang E. Elston

THE GEOLOGY OF THE WHITE OAKS - PATOS MOUNTAIN AREA, LINCOLN COUNTY, NEW MEXICO

by

Richard A. Haines

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Geology
in the Graduate School of
The University of New Mexico
Albuquerque, New Mexico
June 1968

THE GEOLOGY OF THE WHITE OAKS - PATOS MOUNTAIN AREA, LINCOLN COUNTY, NEW MEXICO

by

Richard A. Haines

ABSTRACT OF THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Geology
in the Graduate School of
The University of New Mexico
Albuquerque, New Mexico
June 1968

CONTENT

Page

Page

Igneous Rocks (continued)

ILLUSTRATIONS

Figures

Plates

ABSTRACT

The White Oaks - Patos Mountain area is in the north-central portion of the Sierra Blanca basin in central Lincoln County, New Mexico. The rocks consist of Permian, Triassic, and Cretaceous strata intruded by early Tertiary sills, dikes, and laccoliths. The 2,900 feet of sedimentary strata include 750 to 800 feet of Permian rocks, 550 feet of Triassic rocks, and 1700 feet of Cretaceous rocks. Extensive Tertiary-Quaternary pediments cover much of the area.

The mapped area lies in the center of a large concentration of Tertiary intrusive bodies known as the Lincoln County porphyry belt, including Patos Mountain. Igneous rocks include rhyolite, trachyte porphyry, latite porphyry, diabase porphyry, diabase, and several other minor types. The rhyolite is found only in Patos Mountain and the other types occur as sills and dikes.

The Patos laccolith, aside from doming the Mesaverde Formation above it, contains abundant vertical jointing, which in the contact zone is always either parallel or normal to the contact of the intrusion but in the central zone is diversely oriented. Folding, other than doming by the intrusions, is minor. Faulting is common and the large White Oaks fault has 200 to 2,000 feet of throw. A large fault at the eastern edge of the area has about 1,000 feet of throw.

Minerals which were mined in the area are contact metasomatic deposits of iron, fissure veins of gold with associated tungsten, and bedded deposits of coal.

THE GEOLOGY OF THE WHITE OAKS - PATOS MOUNTAIN AREA, LINCOLN COUNTY, NEW MEXICO

INTRODUCTION

Location

The White Oaks - Patos Mountain area is approximately 15 miles northeast of Carrizozo in central Lincoln County, New Mexico. It includes 80 square miles and is bounded by meridians 105°34' and 105°45' west longitude, and 33°42.5' and 33°49.5' north latitude. It lies mainly in T. 6 S., R. 13 E., but includes parts of T. 7 S., R. 12 and 14 E. It lies primarily in Lincoln National Forest and is heavily wooded, with the exception of the eastern third.

Accessibility

White Oaks is reached by State Road 349 from Carrizozo. Accessibility is generally good by many mining and ranching roads, with the exception of Patos Mountain, where forest service trails must be used.

Physiography

The relief is approximately 2,200 feet, with the highest elevation of 8,508 feet on Patos Mountain. Several points on the eastern margin are as low as 6,300 feet. Patos Mountain, nearly circular in form, is the most conspicuous physiographic feature, rising considerably above the surrounding area. Several of the most resistant sedimentary beds and sills form prominent ridges.

Previous Studies

Very little detailed mapping has been done in the area prior to this investigation. Some local mapping and description of the geology and structure of the iron deposits was done by V. C. Kelley (1949). Lindgren and others (1910) discussed and described all of the mineral deposits in the area. Smith and Budding (1959) published a reconnaissance geologic map of the Little Black Peak Quadrangle, which adjoins the White Oaks - Patos Mountain area on the west. Wegemann (1914) discussed the coal deposits in the area in detail.

Methods

This report is based on approximately 60 days of field investigation done between June 1967 and September 1967. Mapping was done on aerial photographs and was transferred to a planimetric base map by means of a vertical sketchmaster. Approximately 50 thin sections of the igneous rocks of the area were studied.

Objectives

The purpose of this investigation was to determine the exact form and origin of the Patos intrusion as well as to determine the relations of the structural and intrusive elements of the area to the surrounding intrusive bodies, which include the Lone Mountain, Carrizo, and Jicarilla intrusions. Although the emphasis of this investigation was mainly on the structure and petrography of the rocks of the area, stratigraphy and economic geology are also described.

Acknowledgments

Thanks are expressed to Vincent C. Kelley, who introduced the writer to the problem and guided the thesis project in most of its phases. The writer also appreciates the help of J. P. Fitzsimmons for identifications in many thin sections, S. A. Northrop in the identification of many fossils, and L. A. Woodward and W. E. Elston, who read the manuscript and made many helpful comments.

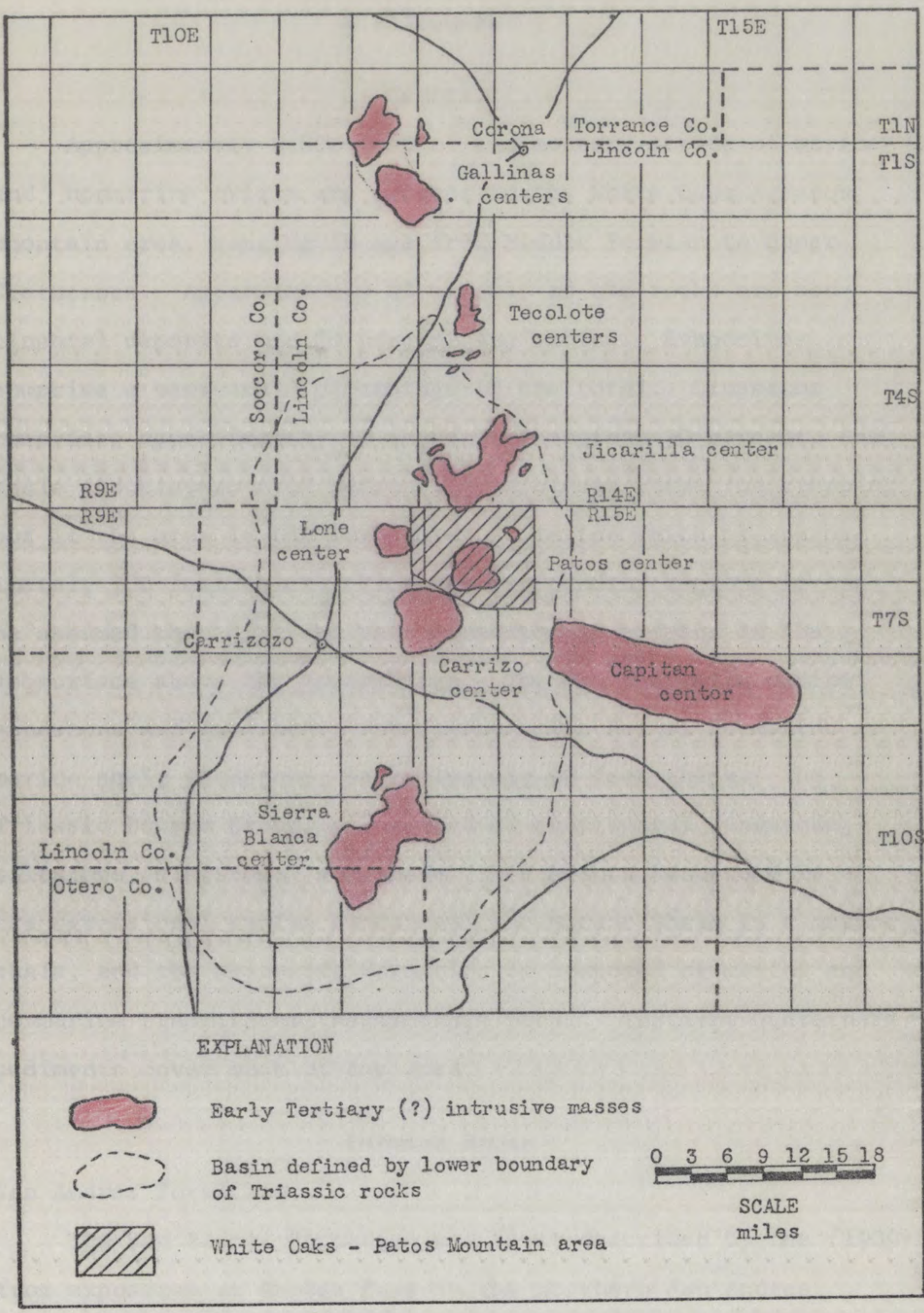


Figure 2. Index map of Lincoln County showing location of White Oaks - Patos Mountain area.

STRATIGRAPHY

General

Approximately 2,800 feet of sedimentary strata of marine and nonmarine origin are present in the White Oaks - Patos Mountain area, ranging in age from Middle Permian to Upper Cretaceous. Approximately 20 percent of the rocks are continental deposits and 80 percent are marine. Evaporites comprise a very small percentage of the total. Limestone comprises approximately 10 percent, sandstone 30 percent, and shale and claystone 60 percent. The oldest formation cropping out in the area is the San Andres Formation which is approximately 700 feet thick. From the surrounding regions it can be assumed that only the Yeso Formation is present in the subsurface above the Precambrian. The San Andres is marine sandstone and limestone, and gypsum. The Bernal Formation is marine shaly sandstone, approximately 90 feet thick. The Triassic Dockum Group is composed of continental sandstone, siltstone, claystone, and shale. The Dakota Sandstone is a transgressional marine sandstone, the Mancos Shale is a marine shale, and the Mesaverde Formation is composed of marine and nonmarine transitional sedimentary rocks. Tertiary Quaternary pediments cover much of the area.

Permian Rocks

San Andres Formation

The San Andres Formation was first described by Lee (1909) from exposures at Rhodes Pass in the northern San Andres

Mountains, Sierra County, New Mexico. It was later described by Needham and Bates (1943) from the same location. In the mapped area the San Andres is divisible into three units: the basal Glorieta Sandstone, a middle massive limestone and an upper gypsum member. Due to intrusions a complete undisturbed section is not present, but the thickness probably exceeds 700 feet.

The Glorieta Sandstone was first named by Keyes (1915) from exposures at Glorieta Mesa, Santa Fe County, New Mexico, and was thought to be Cretaceous. However, Hager and Robitaille (1919) and Rich (1921) have since shown it to be Permian. The Glorieta does not overlie the Yeso Formation in this area but lies directly on the Jicarilla and Lone Mountain intrusions to the north and west. Outcrops of the Glorieta occur only in the north and extreme west and exposures are poor due to disturbance by the underlying intrusions. The Glorieta is fine-grained, buff to brown, massive quartz sandstone, becoming more calcareous toward the top where it grades into the limestone unit. It is approximately 100 feet thick.

Overlying the Glorieta is massive gray, somewhat crystalline limestone containing few fossils. Algal nodules and nautiloids occur with some foraminifera in the lower part. The porosity is quite variable, ranging from pinpoint to vuggy porosity. The majority of the vugs, up to 3 inches wide, are filled with calcite. Some of the more porous zones have the odor of petroleum, and others contain small amounts of chert. Several very thin dark-brown sandstones are present in the limestone unit.

The gypsum unit of the San Andres is extremely nonresistant, is covered by gravel and float, and is not exposed anywhere in the area.

Bernal Formation

The Bernal Formation overlies the San Andres Formation with apparent conformity. The formation was originally defined by Bachman (1953) from exposures near Bernal, Mora County, New Mexico, as the upper member of the San Andres Formation. Others have correlated these beds with the Chalk Bluff, Whitehorse Group, and Upper San Andres. Allen and Jones (1951) have referred to the Bernal as Triassic and upper Guadalupian. In the White Oaks - Patos Mountain area exposures are poor and the relation of the Bernal to the San Andres is questionable. However, from relations in the surrounding region, the Bernal can be described as a facies of the Permian Artesia Group (Kelley, personal communication, 1968). The Bernal is an orange to buff, shaly, nonresistant sandstone, containing small amounts of gypsum and forming a yellow-orange soil. It reaches a maximum thickness of 90 feet and may be missing in some places, either by pre-Triassic erosion or intrusion. No fossils were found in the Bernal Formation.

Triassic Rocks

Santa Rosa Sandstone

Unconformably overlying the Bernal is the Santa Rosa Sandstone of the Dockum Group. The Dockum Group was first described by Cummins (1890) from red-beds in northwestern Texas, and the Santa Rosa was first given formational status by Darton (1922) from exposures near Santa Rosa, Guadalupe County, New Mexico. There is considerable question of the formational status of the Santa Rosa because of its gradational nature in most regions. However, in the White Oaks-Patos Mountain area, a rather sharp transition occurs from the sandstones of the Santa Rosa to the shales of the Chinle Formation. This distinct change in lithology was used as the contact for mapping. Outcrops of the Santa Rosa are fair but occur only in the north and northwest sections of the area. It is composed of thin to medium-bedded, brown, buff, reddish-brown, and gray micaceous quartz sandstone and siltstone with thin interbedded red, brown, and purple shale. A five-foot bed of limestone pebble conglomerate and a thin interclastic limestone breccia occur near the base. Several thin, discontinuous, chert pebble conglomerate beds occur throughout the formation. An estimated 250 feet designated Santa Rosa Sandstone is present in the White Oaks - Patos Mountain area. Smith (1964) reported an average of 200 feet in the Little Black Peak Quadrangle, and Weber (1964) measured 295 feet in the Carrizozo Quadrangle. No fossils were found in the Santa Rosa.

Chinle Shale

The Chinle Shale overlies the Santa Rosa gradationally and is the upper member of the Dockum Group. Gregory (1915) first described the Chinle from exposures in the Chinle Valley in northeastern Arizona. Cummins (1890) defined similar Triassic red-beds in northwestern Texas as the Dockum Group. The Chinle is present throughout the mapped area, but outcrops are poor and limited to the sides of stream channels. The rocks are red, purple, and brown sandstone, siltstone, mudstone, and claystone, with several limestone pebble conglomerates. These rocks weather to red and reddish-brown soil. Sandstone beds are extensively cross-bedded and channelled and frequently contain spherical concretions up to 8 inches in diameter. Although no accurate measurement could be obtained, approximately 300 feet of the Chinle Shale is present. No fossils were found in the Chinle.

Cretaceous Rocks

Dakota Sandstone

The Dakota Sandstone overlies the Chinle Formation with slight unconformity. It was first described by Meek and Hayden (1862) from exposures near Dakota, Nebraska. The name has since been applied to all the basal sandstones of the Upper and Lower Cretaceous in the Rocky Mountains. In the mapped area the Dakota is divisible into three units of approximately equal thickness: a lower white to buff massive quartz sandstone, a white shaly sandstone, and an upper fine to medium-grained brown quartz sandstone. Locally, throughout the upper and lower units, the Dakota is stained dark red and orange with hematite and limonite, although in several places only

PLATE 1

A. Typical outcrop of the Bernal Formation. Note characteristic color and nonresistant nature. Hammer handle is 10 inches long.

B. Typical exposure of the Mancos Shale showing Greenhorn Limestone zone of interbedded limestone and shale. The thickest limestone is approximately 1 foot.

Plate 1

the fractures have been stained. Both the upper and lower units form prominent ridges whereas the middle unit commonly forms a small depression between them. The sandstone weathers red, yellow, and brown with some desert varnish. Ripple marks and cross-bedding are present throughout the upper and lower units. The total thickness measured in the area is 200 feet. This is comparable to the 150 feet which Smith (1964) reported for the Dakota in the Little Black Peak Quadrangle, and the 134 feet which Allen and Jones (1951) reported for the Capitan quadrangle. Plant fossils are abundant throughout the Dakota and many large pieces of wood are preserved in the lower unit.

Mancos Shale

Overlying the Dakota conformably is the Mancos Shale, first described by Cross (1899) from exposures near Mancos, Colorado. The contact between the two is gradational. Outcrops of the Mancos in the area are rare, restricted to freshly cut arroyos and slopes capped by resistant sills. Thin-bedded black and gray shale comprises most of the Mancos in the area, but interbedded limestone beds are present, ranging in thickness from less than one inch to more than two feet. The thicker limestone beds near the middle of the Mancos are correlative with the Greenhorn Limestone in other regions. The limestones are very dense, have hackly fracture, and are remarkably uniform throughout the area. Many shale beds are locally pyritiferous, calcareous, or silty. All the shale beds generally weather to a light-brown soil. The exact

PLATE 2

A. Typical outcrop of Mesaverde sandstone. The ledge is approximately 60 feet high.

B. Detail of fossiliferous sandstone marker bed in Mesaverde Formation. The fossils are most <u>Ostrea</u> sp. and <u>Gryphaea</u> sp. The pencil is 5 inches long.

Plate 2

thickness could not be determined, but is estimated at approximately 700 feet.

Mesaverde Formation

Overlying the Mancos gradationally is an incomplete section of the Mesaverde Formation, which was first described by Holmes (1877) near Mesaverde, Colorado. It is composed of marine and nonmarine sandstone, shale, and several thin coal beds. The sandstone beds are white, buff, dark brown, and red, weathering to darker shades of brown, yellow-brown, and red-brown, with occasional desert varnish. Two sandstone beds, both approximately 150 feet thick, form prominent ridges throughout the area. Many thin sandstone beds are interbedded with the shale beds. The coal beds range in thickness from 4 inches to 3-1/2 feet. Extensive cross-bedding, ripple markings, and channelling occur throughout all the sandstone, while Liesegang banding is also somewhat common. In addition, the upper surfaces of many of the sandstone beds weather to pitted, knobby, or wormy forms, and large blocks weather spheroidally. Many spheroidal concretions were found in the sandstones, some up to 6 inches in diameter. Locally some sandstone has a mottled, spotty appearance due to spotty staining with limonite and hematite.

The shale of the Mesaverde Formation is gray to black with interspersed seams of coal. Exposures are poor and are seen only in arroyos or directly below ridges capped by sandstone or sills. Two highly fossiliferous limy sandstone beds, about one foot thick, serve as excellent marker beds. These beds are composed almost entirely of the pelecypods Ostrea sp., and Gryphaea sp. A thin dark-brown sandstone near the base of the Mesaverde Formation contains abundant gastropods of Gyrodes depressa, Rostellites sp., and the cephalopod Bacculites. Turritella sp., and Inoceramus sp. are also present in the thick sandstones of the formation. About 800 feet of the Mesaverde Formation was measured, although the entire formation is not present.

Tertiary-Quaternary Deposits

Two rather extensive, dissected pediments are present in the White Oaks - Patos Mountain area. The largest surrounds Patos Mountain, except on the south. This pediment grades into a similar pediment on the west which flanks Carrizozo Mountain on the north. On the east of Patos Mountain the pediment is highly dissected. Several small terrace-like remnants of the surface extend up the large canyons of Patos Mountain. The pediment is covered with material derived from Patos Mountain. The fragments range in size from small gravel to large boulders and have a matrix of clay and silt.

The second and less extensive pediment flanks the southern end of the Jicarilla Mountains. This surface appears to be older since it is more dissected than the Patos pediment. It is capped by gravel derived from the limestone of the San Andres Formation and from the alkalic igneous rocks of the Jicarilla intrusion.

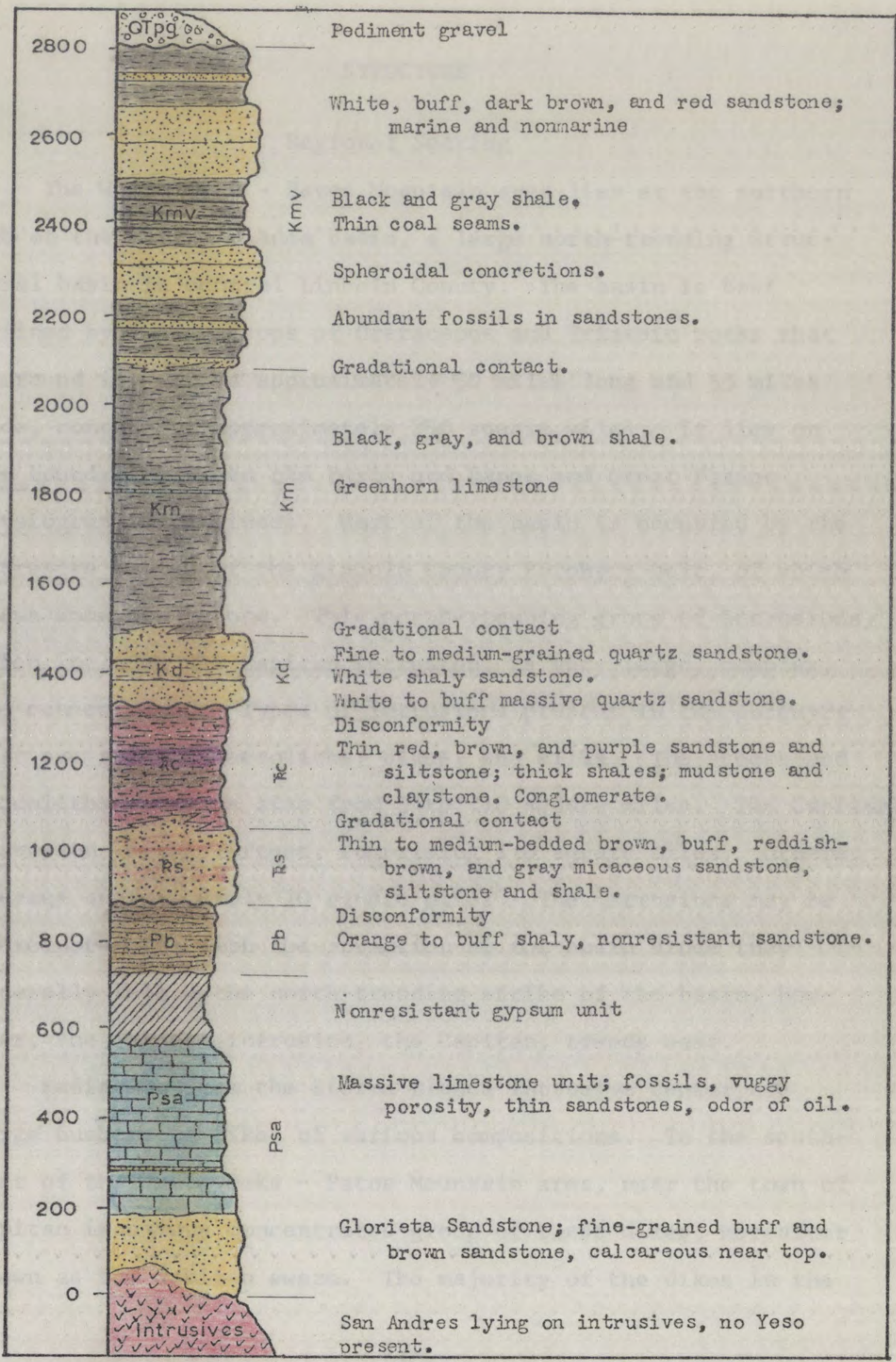


Figure 3 ; Generalized stratigraphic column.

STRUCTURE

Regional Setting

The White Oaks - Patos Mountain area lies at the northern end of the Sierra Blanca basin, a large north-trending structural basin in central Lincoln County. The basin is best defined by the outcrops of Cretaceous and Triassic rocks that surround it. It is approximately 50 miles long and 35 miles wide, containing approximately 750 square miles. It lies on the boundary between the Basin and Range and Great Plains physiographic provinces. Most of the basin is occupied by the intrusive bodies of the Lincoln County Porphyry belt, of which Patos Mountain is one. This north-trending group of intrusions, which includes the Capitan intrusion, is very large, complex, and concentrated. Types of intrusions present in the porphyry belt are stocks, laccoliths, dikes, and sills. The stocks and laccoliths range in size from 5 to 110 square miles. The Capitan intrusion is the largest, comprising 110 square miles. Others average approximately 10 square miles. The intrusions may be contemporaneous with the formation of the basin since they generally follow the north-trending strike of the basin. However, the largest intrusion, the Capitan, trends east.

Radiating from the Sierra Blanca intrusive center are large numbers of dikes of various compositions. To the southeast of the White Oaks - Patos Mountain area, near the town of Capitan is a very concentrated group of these dikes, hereafter known as the Capitan swarm. The majority of the dikes in the in the swarm trend NNE and some extend into the White Oaks-Patos Mountain area.

Most of the faults and folds in the area also have a northeasterly trend, paralleling the basin axis. Rawson (1957) reports a prominent joint pattern in the Tecolote Hills area which also parallels the basin axis.

The most prominent structural features in the White Oaks-Patos Mountain area are the White Oaks fault and the Patos Mountain laccolith. The area lies in the center of the Lincoln County Porphyry belt and is flanked on the north, west, and southwest by the Jicarilla, Lone Mountain, and Carrizozo intrusions. All three intrusions played an important role in the formation of the structural elements of the area.

Structure of the White Oaks - Patos Mountain Area

Structure Related to Intrusions

The doming of the Mesaverde Formation over the flanks of the Patos laccolith is the most prominent structural feature related to intrusive activity. The roof of the laccolith has been removed, but on the south and west the sandstones are dipping gently away from the intrusion and may be projected over the top of the mountain. The same sandstones appear to form the floor of the Carrizozo laccolith directly to the southwest. Outcrops of the Mesaverde Formation on the north and east of Patos laccolith are very limited, owing to extensive gravel cover. However, in those outcrops visible on the north of Patos Mountain, the dip is toward the laccolith.

Typical vertical jointing in the border zone of the Patos rhyolite. The joint plates are approximately 1 inch thick.

PLATE 3

In contrast to the Patos laccolith, the Jicarilla intrusion is irregular and lobate, as evidenced by several remnants of the San Andres Formation that are present on or within the intrusion. The San Andres Formation dips away from the intrusion in all directions.

The Patos laccolith is responsible for considerable sedimentary deformation. It also contains much internal jointing. Vertical or nearly vertical joints characterize every outcrop of the Patos rhyolite. Near the contacts of the laccolith, the joints are almost always normal to the contact. Locally, however, they may parallel the contact. Within the intrusion the strike of the joints varies greatly and the joint plates widen. The joint plates range in thickness from 1/2 to 6-inches and are quite uniform in thickness.

The flow orientation of the feldspars in the rock was nowhere found to be parallel to the joints. Therefore, the joints are more likely the result of cooling rather than intrusion.

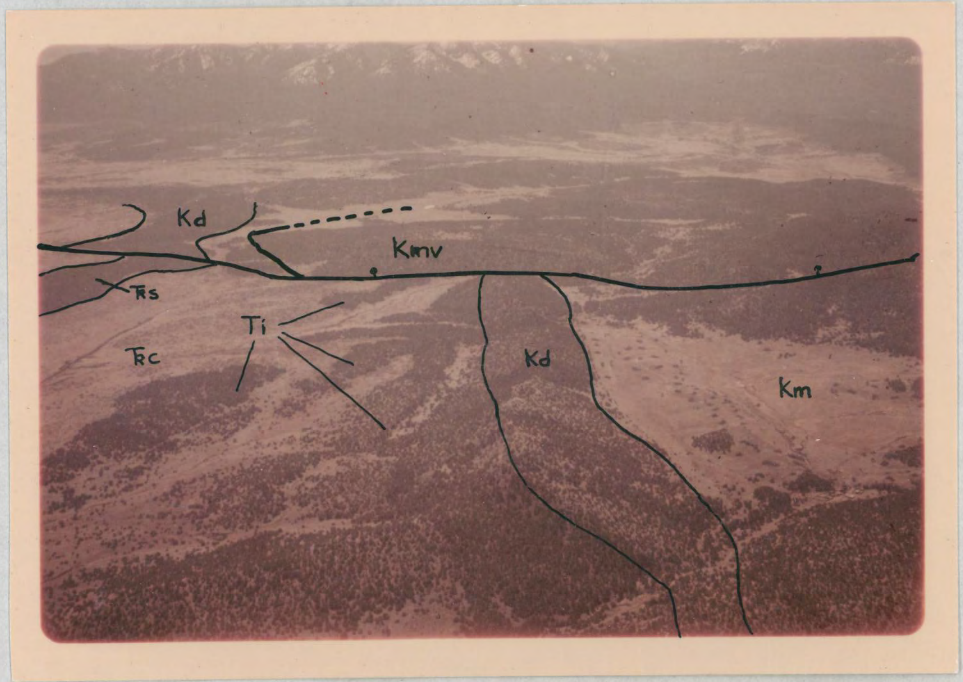
Several of the large sills have caused minor deformation of the beds into which they were intruded. Minor slippage along previous fractures and extensive fracturing of the sandstones are the most common results of sill intrusion. Columnar jointing normal to the contacts is common in the larger sills.

Folds

Several folds are present in the White Oaks - Patos

PLATE 4

A. Oblique view south. The White Oaks fault is shown crossing the center of the photograph. The Dakota Sandstone (Kd) is offset approximately 3,500 feet.



B. Oblique view northeast of the Mancos Shale where it is intruded by abundant sills which are responsible for the ridges in the central part of the photograph. The White Oaks fault is shown in the upper left-hand corner of the picture.

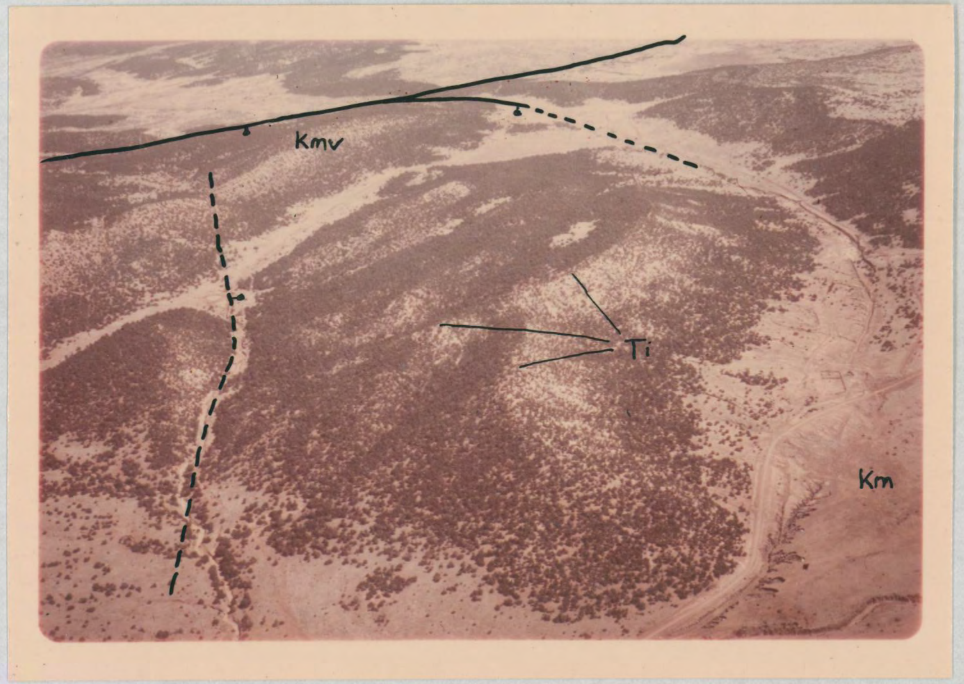


Plate 4

PLATE 5

A. Typical vertical jointing of many of the larger sills. The sill is approximately 50 feet from top to bottom (lower left corner).

B. View south of Patos Mountain and surrounding pediment.

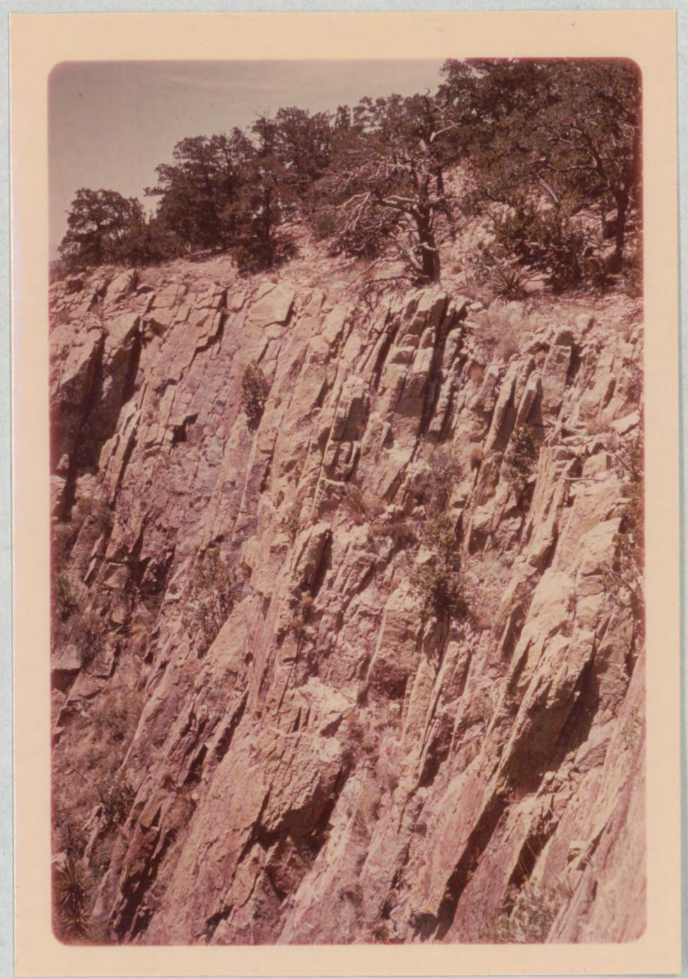


Plate 5

Mountain area. All are gentle, generally symmetrical, and nearly all trend north to northeast. The dip of the limbs of most of the folds is almost always less than 20 degrees. Most of the folds are pre-faulting, probably forming during the early intrusive stages. Some folds, however, such as the asymmetrical fold in section 17, T. 6 S., R. 13 E., appear to be due to faulting. Many folds appear to be a result of intrusion because their axes lie between intrusions. The large north-trending syncline offset by the White Oaks fault is a good example. Several other folds in the north which are related to the Jicarilla intrusion have intrusive rock exposed in the center of the fold. The origin of the small anticline in Section 21, T. 6 S., R. 13 E., is unknown, but it is probably related to an intrusion at depth. The relief on this fold is approximately 1,000 feet.

Faults

Faulting is important but uncommon in the area. The majority of the faults are short and vertical with little displacement. Two faults, however, have very large displacements. The White Oaks fault is the larger of the two and forms an arcuate pattern across the area from northeast to southwest. It continues south and northeast for several miles beyond the mapped area. It is a normal fault, downthrown on the southeast, dipping approximately 80 degrees southeast. The maximum throw of 2,000 feet was measured in two places: (1) where the Dakota Sandstone is offset (Secs. 8 and 17, T. 6S., R. 13 E.), and

(2) on the east flank of Lone Mountain. Left offset of the Dakota Sandstone is approximately 200 feet at the northeast boundary line. At the point where the White Oaks fault begins curving south, it bifurcates into two faults. Both are downthrown on the southeast and join again into one fault after 1-1/2 miles. Some transcurrent movement may have occurred on the White Oaks fault. The formation of the White Oaks fault does not appear to be associated with the intrusion of the surrounding stocks and laccoliths. It is probably associated with the regional deformation and has derived its arcuate pattern due to deflection by the resistant intrusive masses.

The second large fault trends north along the eastern edge of the area. Its total length cannot be determined because both ends of the fault are covered by pediment gravel. On the north the fault probably joins the White Oaks fault. The fault is vertical, downthrown on the east, and has a throw of approximately 1,000 feet. Left offset of the Dakota Sandstone is approximately 3 miles.

Several other faults are present and in general parallel the White Oaks fault. These are probably related to the many intrusions in the area or to movement on the White Oaks fault. The fault in Sec. 17, T. 6 S., R. 13 E. has an unusual northwest trend. The throw is a maximum of 600 feet at the White Oaks fault, decreasing to less than 100 feet in Section 20. Possible right lateral transcurrent movement on the White Oaks fault may be responsible for this fault, and for the bifurcation of the White Oaks fault. Displacements of other faults in the area range from 500 to less than 50 feet.

Tectonic History

Beds older than middle Permian are not exposed within the area. However, in the Sacramento Mountains to the south, early Paleozoic marine sediments were deposited. In the Heard-Federal No. 1 test for petroleum, 8 miles northwest of Carrizozo, marine Pennsylvanian sediments are present on Precambrian gneiss. East-west arching during Mississippian time was responsible for removal of the lower Paleozoic sediments across south-central New Mexico (Kelley and Furlow, 1965). The buried Pedernal Mountains, which flank Sierra Blanca basin on the east, were formed during late Pennsylvanian and Permian time (Pray, 1961). In some places on the Pedernal arch, the entire Pennsylvanian section was removed by erosion. The Yeso Formation is known to occur in the subsurface in the mapped area from the Ray N. Sipple No. 1 Kelt. In the area near Carrizozo a persistent evaporite basin formed during Yeso time. The evaporites were later buried by a transgressing sea during deposition of the San Andres Formation.

Triassic continental deposits are part of either an erosional or depositional wedge edge, thinning to the south. The wedge edge thins until in the Sierra Blanca area, there is no Triassic or Jurassic present (Thompson, 1966). Lack of Jurassic sediment in the White Oaks - Patos Mountain area indicates either nondeposition or erosion. Transgression of the Cretaceous Dakota Sandstone over Mesozoic and late Paleozoic sediments from north to south indicates renewed arching along the old Mississippian arch trend. The arching may have occurred during late Jurassic.

The major effect of the Laramide was downwarping of the Sierra Blanca basin. The buried Pedernal Mountains caused faulting in the east parallel to the basin axis (Thompson, 1966).

The Sierra Blanca volcanics were extruded in the early Oligocene. Intrusion of the basic dikes and sills in the area occurred during extrusion of the andesitic volcanics. Intrusion of the felsic porphyries was late Oligocene (Thompson, 1966). Faulting occurred after intrusion and was concentrated in the east of the Sierra Blanca basin. The White Oaks fault was formed at this time.

Extensive pedimentation occurred during the late Tertiary and Quaternary as the resistant intrusive rocks were uncovered.

IGNEOUS ROCKS

Occurrence and Types

Igneous rocks occur in abundance throughout the White Oaks - Patos Mountain area in the form of sills, dikes, and laccoliths. Sills are the most common type by far and occur primarily in the shale beds, although some are found in the thin-bedded sandstones. Thicknesses differ from sill to sill as well as within individual sills. They range in thickness from less than 2 feet to 50 feet. In some areas the concentration of sills cannot be distinguished. To further complicate mapping, the shale units in which the sills are found are disturbed and are covered with abundant float material. The areas of thick sill concentration are shown diagramatically in Figure 1.

The sills occur in two concentrated areas: (1) the northwest quarter and (2) the east-central sector of the area (Fig. 1). These two areas represent two distinct petrologic groups as well as two distinct ages of intrusion. Those in the east-central sector are diabasic and are older than those in the northwest, which are alkalic porphyries. The division between the two groups is rather sharp. None of the rocks common in the northwestern area are found in the diabase area, and only one diabase sill was found in the northwest quarter.

Several dikes occur within the area and they are probably a part of the Capitan dike swarm. The trend of all the dikes in the area coincides with the average strike of the dikes in the Capitan swarm. Some of the dikes are porphyritic and all are aphanitic.

Laccoliths present are the Patos and Jicarilla laccoliths. A detailed description of the Jicarilla intrusion is not given here since a thesis on it is presently in progress, and only a small portion of the intrusion is included in the mapped area. The Patos laccolith is almost circular in map view, occupying approximately 8 square miles. The relief of the mountain formed by the laccolith is approximately 1,500 feet. The depth and areal extent of the intrusion under the surrounding apron of gravel as well as the location of a feeder could not be determined. The laccolith seems to be thicker at the north end.

Sills

Form and Size

The sills in the area range in thickness from less than 2 feet to 50 feet. Many maintain their thickness throughout their areal extent and others are lenticular. Many do not occupy the same horizon throughout their areal extent, but migrate vertically within the shales. Due to their abundance, outcrops of the sills in the northwest quarter of the area are shown diagrammatically in Figure 1. The shale into which the sills have been intruded is rarely visible because float material from the many sills completely covers the slopes.

Structure and Metamorphism of the Intruded Rocks

Most of the rocks intruded by the sills have experienced little deformation. The shale beds, however, are generally greatly disturbed at the contacts with the sills. Sandstone beds near sills generally contain abundant minute slickensides which are almost always aligned approximately normal to the bedding. Some small faults were found related to the sills, probably caused by intrusion, but in no instance was the displacement more than 15 feet. Very little isochemical or metasomatic alteration of the shale and no alteration of the sandstone could be observed. Bleaching and baking of the shale in contact with the diabase sills was the maximum alteration observed. In some cases, no alteration was observed even where sills were seen in direct contact with sedimentary rocks. No brecciation was observed at any sill contacts.

Viscosity of the Intrusive Magmas

The viscosity of the sill magmas was probably high, and the magma was intruded very slowly, causing a slow dilation of the bedding without brecciation. Large fractured phenocrysts, found mostly in the alkalic sills, are a good indicator of high viscosity. The presence of slickensides in the sandstones indicates that the magma had a high transmission of pressure. A low viscosity magma would not be able to transmit much pressure vertically or have the strength to support the domed beds. Barth (1962, p. 137), has found that acid magmas have higher viscosities than basaltic magmas and that zoning is commonly found in magmas with high viscosity. The alkalic sills in the area commonly contain zoned feldspars whereas the diabase sills do not. The viscosity of the diabase magma was much lower than the viscosity of the trachyte and latite. Further proof lies in the fact that each diabase sill is uniform in thickness and generally thinner than the alkalic sills.

Temperature of the Intrusive Magmas

The temperature of the intrusive magmas cannot be determined definitely. However, the temperatures of both types were probably in the vicinity of 400°C. The diabase magma was hotter than the alkalic as abundant baking and bleaching of the shale in contact with the sills has occurred. Small amounts of epidote occur in some of the shale beds in contact with the diabase. The presence of sanidine in many of the alkalic sills suggests a much higher temperature than 400°C. However, it is likely that the sanidine phenocrysts formed at depth before intrusion since the formation temperature of the sanidine does not coincide with the grade of alteration at the contacts of the sills.

Age of the Sills

The age of the sills can be determined only on a relative basis. The diabase sills are the oldest and are probably related to the diabasic stage of the Capitan dike swarm. The alkalic sills are the youngest and are related to the intrusion of the laccoliths and stocks which surround the area. Elston (1964) found that the intrusion of the dikes in the Capitan swarm followed a series from basic to alkalic. Weber (1964) found gabbroic sills cross-cutting syenite sills in the Carrizozo Quadrangle. Since there are no cross-cutting relationships in the White Oaks - Patos Mountain area, relative ages are indefinite. However, since many of the sills are probably associated with the Capitan dike swarm, it may be assumed that the diabase is oldest.

Petrography

Trachyte Porphyry

Trachyte prophyry occurs entirely as sills throughout the northwest quarter of the area. The color is light brown to white, weathering brown and reddish-brown, depending upon the quantity of mafic minerals present. The texture is always porphyritic, with phenocrysts of sanidine and oligoclase up to 1 cm. in length. The matrix is allotriomorphic holocrystalline with all crystals smaller than 0.1 mm. Zoning of the plagioclase phenocrysts is common. A maximum change in extinction of 20 degrees was observed in the albite twins, indicating an andesine center and an oligoclase-albite border. Euhedral apatite and sphene are common accessory minerals. A representative sample of trachyte porphyry (Sample 7-20-5, Appendix) consists of the following:

Minerals	Percent
Sanidine or orthoclase	75
Plagioclase (Ab_{65-75})	19
Magnetite	2
Hornblende	2
Biotite	1
Apatite	tr
Sphene	tr
Quartz	tr

Many parts of the trachyte prophyry are glomeroporphyritic or cumulophyric, with alkali feldspar in large clusters. Biotite, magnetite, and apatite commonly form small clusters. In most samples alteration of the feldspars to sericite and kaolinite is intense, and only the centers of large phenocrysts are preserved.

Latite Porphyry

Latite porphyry occurs entirely as sills and only in the northwest quarter of the area. A representative sample of latite porphyry (Sample 7-10-3, Appendix) consists of the following:

Minerals	Percent
Sanidine or orthoclase	58
Plagioclase (Ab_{50-70})	40
Biotite	1
Magnetite	1
Sphene	tr
Apatite	tr

The rock is light brown to light gray, weathering to darker shades of brown, depending on the mafic mineral content. It is aphanitic porphyritic with phenocrysts of sanidine, orthoclase, and plagioclase up to 6 mm in length. Orthoclase and sanidine form the largest phenocrysts, whereas augite, hornblende, biotite, and sphene frequently exceed 2 mm in length. The matrix is seriate hypidiomorphic, composed mainly of feldspars. Hornblende and augite are common, never occurring together, but in some sills neither is present. The composition of the latite porphyry is the most variable of all the intrusives. All minerals present vary widely in percentage. Many of the larger plagioclase phenocrysts are zoned but none has a reaction rim or overgrowth of alkali feldspar. Alteration of the feldspars to sericite is common and sometimes severe.

The origin of the latite and trachyte porphyries cannot be determined since no feeder dikes of similar composition were found. Since the sills contain no quartz, they probably are not related to the Patos laccolith and may be contemporaneous with the Lone Mountain or Jicarilla intrusion.

Diabase

Diabase occurs primarily as sills in the east-central sector of the area, but extends into the west-central sector. Before being offset by the large fault in the east, the diabase occurred as one line of outcrops approximately 12 miles in length. On the east of the fault at present the diabase is one sill, but splits into many thin sills on the west side of the fault and to the north. Its most common stratigraphic horizon is the shales of the Mancos Shale. A representative sample of diabase (Sample 6-17-4, Appendix) consists of the following:

Minerals	Percent
Plagioclase (Ab_{40-70})	74
Augite	17
Magnetite	6
Biotite	2
Apatite	1
Epidote	tr

The rock is dark gray to light gray, appears somewhat bluish and weathers gray. The fabric is hypidiomorphic, felty to diabasic, and sometimes porphyritic with large poikilitic phenocrysts of plagioclase. The name diabase has been used here for all rocks with the above composition, although not all have diabasic texture. The rock is very finely crystalline, with the average size of the matrix crystals less than 0.25 mm in length. Olivine is present in some samples in amounts less than 5 percent, and pyroxene ranges from 15 to 25 percent, and plagioclase from 65 to 80 percent. Magnetite and apatite occur in the relatively high maximum percentages of 7 and 2 percent, respectively. The origin of the sills is probably contemporaneous with the No. 3 and No. 4 phases of intrusion of the Capitan dike swarm. (Elston and Snider, 1964)

Miscellaneous Sills

Several other rock types similar to those discussed above are present as sills. They are, however, very few in number and occur only as individual sills. They range from hornblende trachyte to hornblende basalt or lamprophyre, and all are porphyritic. Petrographic analyses of several of these are included in the appendix.

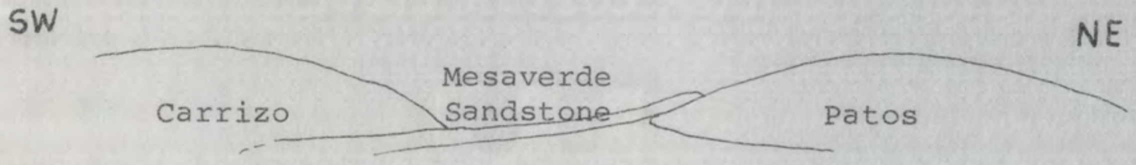
Patos Laccolith

Form and Size

The Patos laccolith is almost circular in plan and comprises 8 square miles. It is believed by the writer to be roughly mushroom-shaped in cross section with the floor sloping toward the center, although no direct evidence was found. On the north side of the laccolith, sandstone of the Mesaverde Formation appear to dip directly under the intrusion with no upturning at the contact. However, the extensive gravel cover which surrounds the mountain covers the contact.

Nature of Intruded Rocks

The Patos laccolith was intruded wholly into the Mesaverde Formation and was restricted by the resistant sandstone. The intrusion has caused a doming of the Mesaverde Formation. However, no sedimentary rocks were observed lying on the intrusive rock in the interior of the mountain. Only at the outer contacts of the laccolith can the sandstones be seen dipping away from the intrusion. The roof of the laccolith was irregular, formed by more than one sandstone horizon. This is evidenced by following the sandstone which forms the roof on the south around the west side to the north, where it appears to form the floor. The roof-forming beds on the north and east have been removed. The sandstone horizon which forms the roof on the south side of Patos laccolith appears to form the floor of Carrizozo laccolith, 1/2 mile to the southwest.



Alteration of the intruded rock is generally slight. However, near the south end of the laccolith abundant hornfels was found. The sandstone shows no alteration even where seen in close contact with the intrusive rock. A very thin zone of crumpling and brecciation occurs everywhere at the contact.

Viscosity of the Intrusive Magma

Viscosity is undoubtedly the most important factor in controlling laccolithic intrusions. It has been discussed by many investigators and is well summarized by Hunt and others (1953) in their study of the Henry Mountains region. They state that an increase in viscosity of a magma would result in greater upward thrusting rather than transmission of pressure laterally. The marginal cooling of magma being injected would also increase upward thrusting by restricting lateral movement of the magma. The region of greatest pressure would be directly over the conduit and the resultant form would be convex upward. The overlying strata would be arched highest over the conduit (Hunt and others, 1953, p. 145-146).

Low viscosity magmas are able to transmit the greatest lateral pressure and will form sills whereas high viscosity magmas transmit little lateral pressure and will form stocks and laccoliths. The extremely fine crystalline border zone of Patos Mountain may have been responsible for the doming of the Mesaverde Formation. Flow orientation of the rhyolite is not vertical as would be expected in a stock, but is oblique to the contact. Many quartz xenocrysts are present in the border zone, probably derived from the sandstone roof.

Temperature of the Intrusive Magma

The temperature of the intrusion cannot be definitely determined. However, some alteration of the shales has occurred, placing the alteration in the albite-epidote-hornfels facies of contact metamorphism. This indicates a temperature of 400°C or less at the contact at the time of intrusion. The magma was probably intruded at a shallow depth to account for the chilled border.

Age of the Intrusive

The most definite date that can be assigned to the Patos laccolith is post-Cretaceous. Thompson (1966) has assigned an age of late Oligocene to the Sierra Blanca intrusives and believes them to be contemporaneous with the other intrusions of the Lincoln County porphyry belt as late Eocene to Oligocene.

Petrography

Rhyolite

Rhyolite occurs only in the Patos laccolith, its composition differing widely. A representative sample from the contact zone, one from the central zone, and the average of all rhyolite samples is shown below.

Contact Zone, Sample 8-5-2

Minerals	Percent
Orthoclase (?) or alkali feldspar	55
Quartz	43
Magnetite	1
Biotite	tr
Epidote	tr
Apatite	tr

Central Zone, Sample 9-3-2

Orthoclase (?) or alkali feldspar	60
Plagioclase (Ab_{60-70})	10
Quartz	15
Magnetite	2
Biotite	3
Hornblende	1
Apatite	tr

Average Percentages for all Rhyolite Samples

Orthoclase (?) or alkali feldspar	52
Quartz	34
Plagioclase (Ab_{55-90})	9
Magnetite	2
Biotite	1
Hornblende	1
Apatite	tr
Epidote	tr

As the samples show, the Patos rhyolite is heterogeneous, especially with respect to composition, but also with respect to grain size. The most striking feature of the rhyolite is the decrease in the percentage of quartz from the contact to the center of the laccolith (Fig. 4). At the contacts the rock is pale brown to white, weathering light reddish-brown to brown. It is aphanitic, seriate, and holocrystalline. Matrix grains are less than 1/4 mm in length and phenocrysts are as long as 3 mm. The crystals are dominantly anhedral to subhedral with only the apatite, biotite, hornblende, and magnetite forming euhedral crystals. Phenocrysts of alkali feldspar are subhedral to euhedral, and phenocrysts of quartz tend to be round. It is believed by the writer that the quartz grains are in fact xenocrysts derived from the sandstone into which the magma was intruded, since no rounded quartz grains are found more than 1,000 feet in the intrusion. A very fine reaction zone around all of the quartz xenocrysts suggests that the quartz was derived from outside the magma. In addition, all the quartz which is actually derived from the magma is anhedral and fills in the spaces between the feldspar laths. Throughout the contact zones are many very small spherical, symplectic, "vermicular-like" intergrowths of quartz and alkali feldspar. The spherules are sometimes as large as 0.2 mm in diameter, but in all cases the intergrowths are too fine to determine the exact type of feldspar present. Some orientation of the feldspars is visible and does not parallel the joints. In general, the feldspars are not aligned vertically, but are oblique or normal to the contact of the intrusion.

The central zone does not differ in color from that of the contact zone and is only slightly more phaneritic. Mafic minerals increase slightly in the central zone but still comprise less than 10 percent of the rock. The matrix crystals remain dominantly anhedral to subhedral, but the phenocrysts are larger. Nearly all phenocrysts in the central zone are plagioclase (Ab_{55-75}), usually rimmed with alkali feldspar, either as an overgrowth or a reaction rim. The quartz content decreases to the point that the central zone may be called a quartz-rich microsyenite. Plagioclase is generally restricted to the central zone. The mafic minerals, including apatite, tend to form in clusters, imparting a porphyritic appearance to the rock. No symplectic, "vermicular-like" intergrowths were observed in the central zone. An unusual texture of the alkali feldspars, observed in many samples, occurs in both zones. This texture is characterized by very fine perthitic-like intergrowths that always occur normal or near normal to the long axis of the crystal. In some twinned crystals the intergrowths appear to intersect at an angle. In every instance, however, the crystals were much too small to obtain any definite petrographic data on the intergrowths. The feldspar associated with these intergrowths is most likely anorthoclase. Alteration of the feldspars to sericite and kaolinite has occurred in both zones, but is more intense in the central zone.

Dikes

The only dikes observed in the area are diabasic and of a type associated with the Capitan dike complex. The dikes are found northeast of Patos Mountain and parallel the trend of the dikes in the Capitan complex. They are continuous for lengths up to one mile and do not exceed 25 feet in width. No

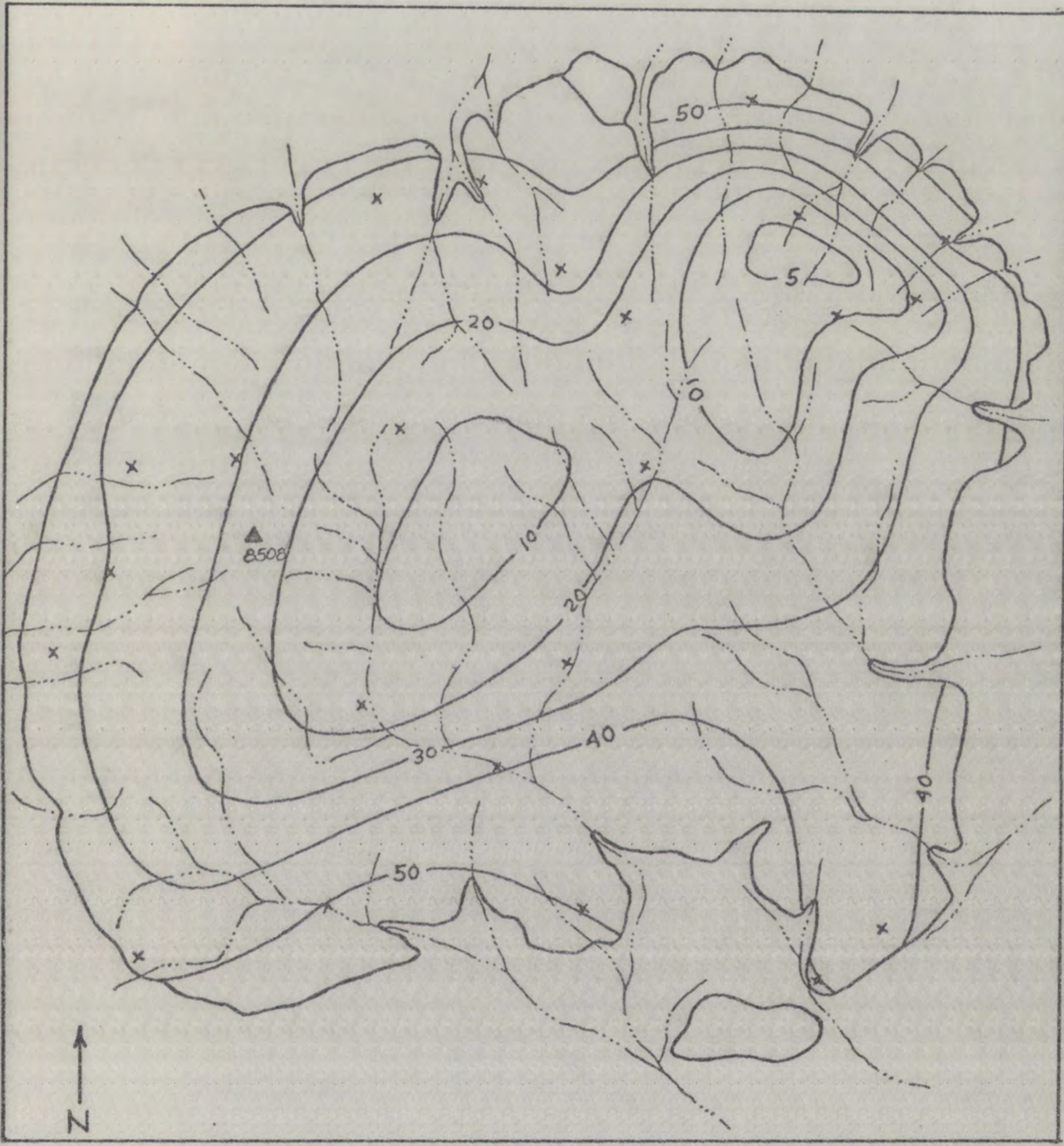


Figure 4. Index map of Patos Mountain Laccolith showing approximate percentages of quartz.

× Location of samples studied

0 ½ 1
miles

alteration of the wall rock was observed as the dikes crop out in gravel. Viscosity and temperature were the same as in the diabase sills because the dikes most likely acted as feeders for the sills. The composition of the dikes in the mapped area and those in the Capitan swarm are similar. The age of the dikes in the Capitan region are early Oligocene (Thompson, 1966, p. 81), and therefore the dikes in the White Oaks - Patos Mountain area are probably early Oligocene. The petrography of the diabase dikes is the same as that of the diabase sills.

ECONOMIC GEOLOGY

General

Many different types of material have been mined in the White Oaks - Patos Mountain area. Foremost of the metals mined is iron ore, which is associated with the Jicarilla and Lone Mountain intrusions. Gold has also been mined extensively in association with the Lone Mountain intrusion. During World War I a considerable amount of tungsten was produced from the area. A small amount was produced from the area during World War II. Several small deposits of coal have been mined in the area southeast of the village of White Oaks. In addition, two shallow tests for oil have been made in the area.

Iron Ore

Two iron districts are present in the region, the White Oaks and Jicarilla districts. Neither is included wholly in the mapped area. All deposits are pyrometasomatic, bordering early Tertiary intrusives.

White Oaks District

Only a few small shafts in the White Oaks district are included in the mapped area, and these produced only a very few tons of ore. The most productive mines in the district are found just to the west of the area on the south slope of Lone Mountain. The ore consists of dense hematite, but some magnetite and specularite are present. Ferroan and manganoan carbonate is present in the low grade margins of the ore and locally this has been concentrated into pods and small masses of supergene hematite, limonite, and pyrolusite.

Narrow zones of actinolite and epidote occur between the ore and the igneous rock. Early assays show that the ore contained 20-60 percent iron (aver. 58%), 0.2-6 percent copper, up to 0.02 oz. gold, and traces of silver.

The ore is found in complexly folded sedimentary rocks around Lone Mountain. The mines consist of underground and surface cuts. The ore bodies are dominantly elongate, following the bedding of the San Andres Formation. Inferred and indicated reserves of the White Oaks district are approximately 45,000 tons (Kelley, 1949).

Jicarilla District

The Jicarilla district is comprised of deposits scattered throughout the Jicarilla Mountains. The deposits discussed in this paper are on the extreme southern slope of the mountains. The ore is composed mainly of dense hematite and magnetite. The gangue and the walls of the ore bodies are highly altered to kaolinitic material. All the deposits are pyrometasomatic, occurring in the San Andres limestone near the contact with the intrusion. The deposits are small elongate and tabular masses, and the ore was mined from shallow cuts by bulldozers. The ore, averaging about 50-60 percent iron, is found in many small deposits, only a few of which are minable. The total output of the district was 7,749 tons, of which about 830 tons came from the mapped area. Reserves are estimated to be 8,000 tons (Kelley, 1949).

Gold

White Oaks District

The White Oaks district is the most famous gold district in central New Mexico. From 1879 to 1904 production amounted to 143,000 ounces of gold valued at $2,800,000. Little mining has been done since that time. The deposits are on the extreme western edge of the area, associated with the Baxter Mountain intrusion south of Lone Mountain. The ore is in quartz-pyrite veins which are commonly found as narrow streaks or stringers. Most of the production is from ore containing free gold, but much of the ore contains gold associated with limonite and pyrite. Other associated minerals in the veins are albite, fluorite, tourmaline, and hubnerite. The altered wall rock contains carbonate, epidote and serpentinized material (Lindgren and others, 1910).

Tungsten

Tungsten was mined in the White Oaks district only during the two world wars. Very little information could be found concerning the tungsten produced in the area. Production during World War II amounted to 554 tons valued at $12,952. Production during World War I is unknown but considerably more was produced.

Coal

White Oaks District

Approximately 15 coal prospects and mines are located to the southeast of the village of White Oaks. Gravel-covered slopes make correlation and mining of the coal difficult. At least three prospects were mined extensively: (1) the Wells and Parker mine, (sec. 5, T. 7 S., R. 13 E.); (2) the Old Abe mine (sec. 5, T. 7 S., R. 13 E.) and (3) the Wild Cat mine (sec. 32, T. 6 S., R. 13 E.). Production of the mines up to 1913 is listed below.

	Wells and Parker	Old Abe	Wild Cat
1895	3506 tons	----	----
1896	4910	----	----
1897	----	----	----
1898	----	----	----
1899	----	----	----
1900	----	4246	----
1901	----	3342	----
1902	----	2391	----
1903	----	2096	----
1904	----	1500	----
1905	----	890	----
1906	----	650	----
1907	----	1160	----
1908	----	1530	----
1909	----	?	----
1910	----	2065	----
1911	----	1658	----
1912	----	538	2012
1913	----	124	2656
	8416	20310	4668

Several other small prospects in the district produced small amounts of coal. The section of coal mined in the Wild Cat mine is as follows (from Wegemann, 1914).

Shale

Coal	6"	
Bone	2"	
Shale, black	1'6"	
Bone	3-1/2"	
Coal	8-1/4"	Mined
Bone	1-1/4"	
Coal	11"	
Coal, impure	1"	
Shale, black	2'6"	
Coal	8"	
	7'5"	

The coal is in the bituminous class, low in sulphur, but high in ash and oxygen, both of which reduce its heating capacity.

Oil

Exploration for oil in the White Oaks - Patos Mountain area has been limited due to intensive intrusive activity in the area. Two tests, however, have been drilled in the mapped area. The deepest test, the Ray N. Sipple No. 1 Kelt, is in sec. 29, T. 6 S., R. 13 E. It was drilled in 1949 and bottomed in red shale, probably the Yeso Formation, at 1,027 feet. The other test was drilled some two miles northeast of the first test. This well, the Mark Vaughn No. 1 Crenshaw, is in sec. 21, T. 6 S., R. 13 E. It reached a total depth of 400-feet in the Dakota Sandstone (Havenor, 1964).

APPENDIX

PETROGRAPHIC ANALYSES OF THE IGNEOUS ROCKS

Introduction

The system of classification and the terminology used is primarily that of Travis (1955), modified somewhat by Fitzsimmons. Since no feldspathoids are present, the rocks are classified according to the percentage of quartz and to the ratio of alkali feldspar to total feldspar. The somewhat condensed classification is as follows:

	ALKALI FELDSPAR 2/3 TOTAL FELDSPAR	ALKALI FELDSPAR 1/3 to 2/3 TOTAL FELDSPAR	ALKALI FELDSPAR 1/3 TOTAL FELDSPAR	NO ALKALI FELDSPAR
QUARTZ ≥ 10%	RHYOLITE (porphyritic)	QUARTZ LATITE	DACITE	
QUARTZ < 10%	TRACHYTE PORPHYRY (MICROSYENITE)	LATITE PORPHYRY	ANDESITE PORPHYRY	BASALT PORPHYRY DIABASE

The term microsyenite is used for rocks in the central zone of the Patos laccolith to distinguish them from the trachyte porphyry, which occurs only in sills. The term diabase is used for the medium-grained sills which are basaltic in composition, but have diabasic texture.

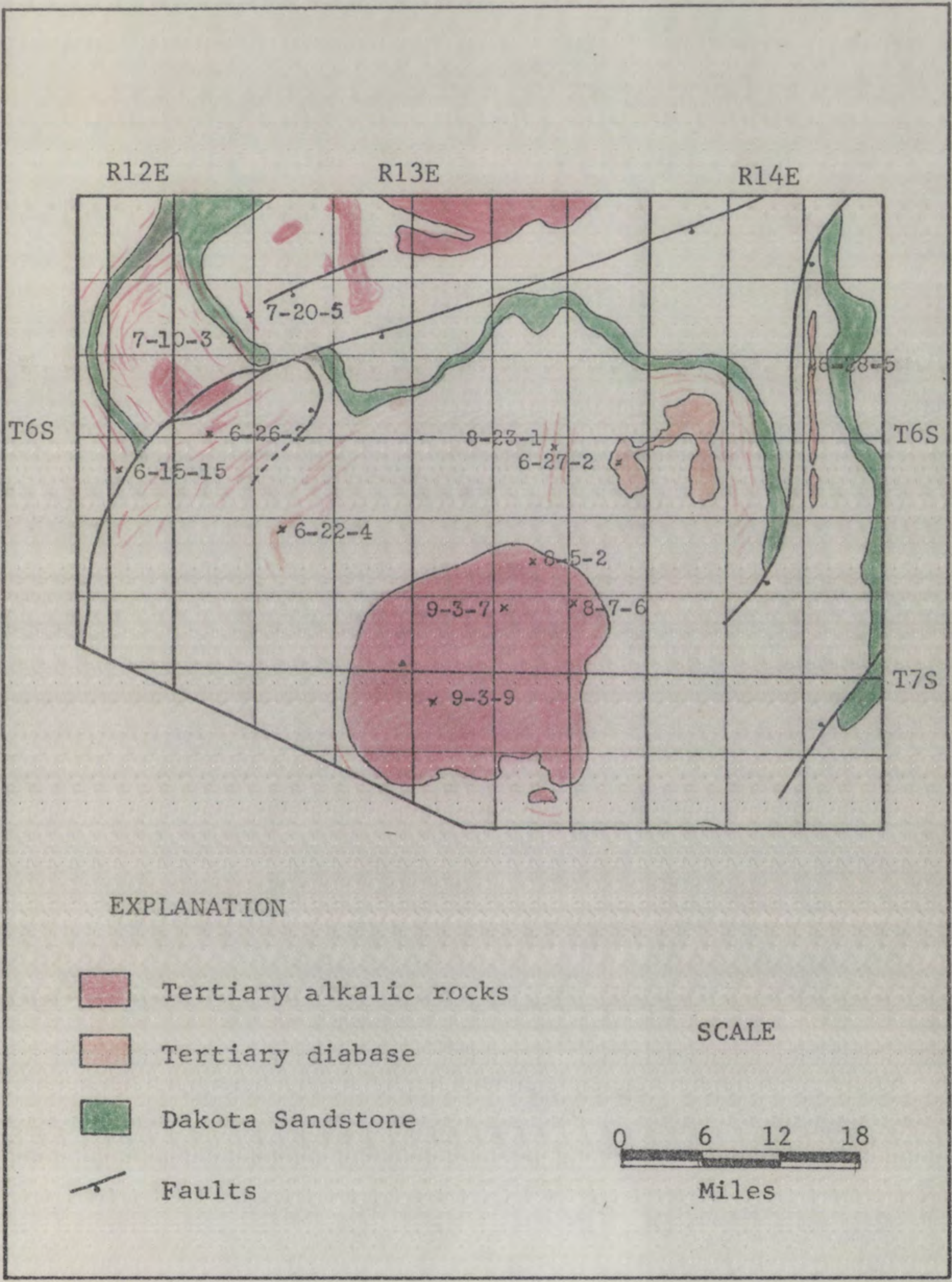


Figure 5. Index map of White Oaks - Patos Mountain area showing locations of samples described in thin sections.

Abbreviations used in plates of thin sections

Q = Quartz

Mg = Magnetite

Or = Orthoclase

Pl = Plagioclase

Hbl = Hornblende

Ap = Apatite

Py = Pyroxene

B = Biotite

Sample 9-3-7

Name: Rhyolite

Texture: Holocrystalline, hypidomorphic to allotriomorphic, felty to trachytic, aphanitic, sub-porphyritic, aver. size of matrix < 0.1 mm. seriate.

Minerals	Percent	Characteristics
Alkali feldspar and orthoclase	66	2V = 75°, phenocrysts up to 3 mm long, overgrowths on plagioclase.
Plagioclase (Ab_{80})	15	Ext. = 12° Michel-levy and 0° A-Normal. Centers of large phenocrysts overgrown by orthoclase.
Quartz	15	Anhedral masses between laths of feldspar. No xenocrysts.
Magnetite	2	Small (0.2 mm) euhedral to subhedral crystals.
Biotite	1	Red, nonpleochroic, no birds-eye maple extinction.
Hornblende	1	Anhedral interstitial masses, Ext. = 27°, z:c, slightly pleochroic, light-green to brown.
Apatite	tr	Very small rods scattered throughout.
Zircon	tr	Very few small crystals.

Remarks: No symplectic, "vermicular-like" intergrowths of quartz and alkali feldspar. Biotite and magnetite occur together in clumps.

Sample 8-5-2

Name: Rhyolite

Texture: Holocrystalline, allotriomorphic, seriate, aphanitic aver. size matrix, < 0.1 mm, phenocrysts up to 2 mm long.

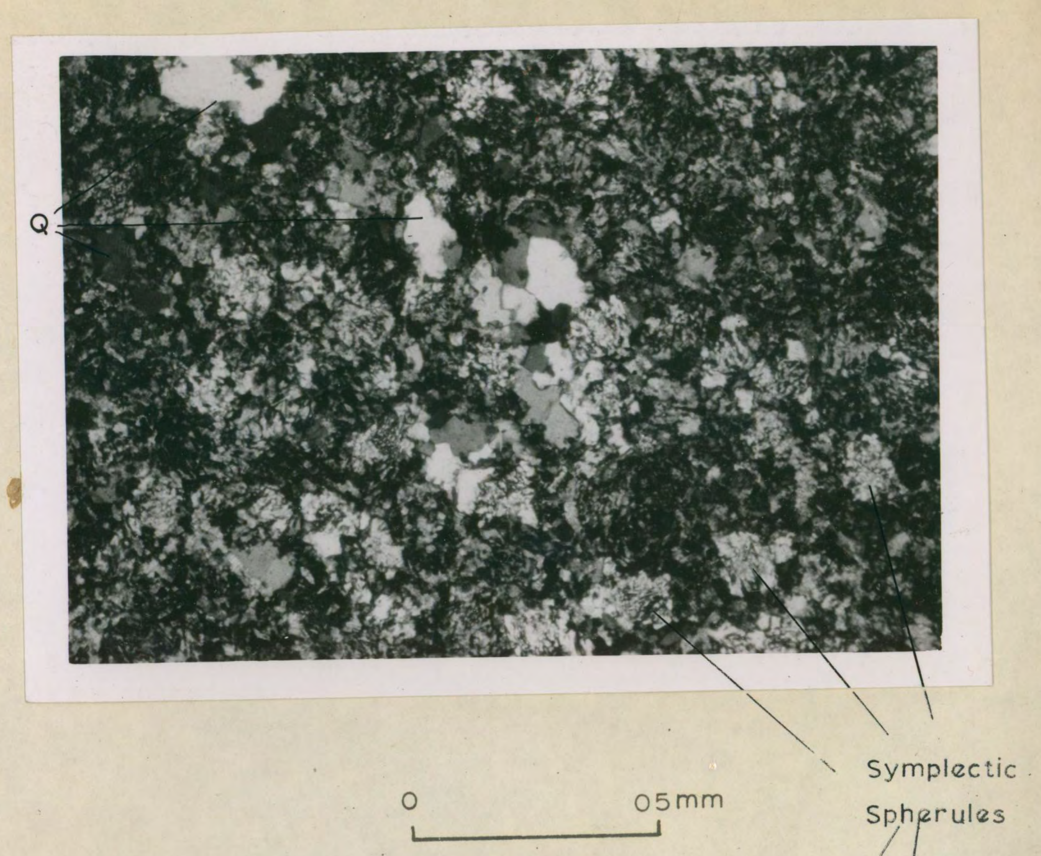
Minerals	Percent	Characteristics
Orthoclase and Alkali feldspar	55	2V = 70°, phenocrysts up to 2 mm long, lath-shaped matrix as well as symplectic intergrowths.
Quartz	43	Few (2%) xenocrysts, anhedral masses between feldspars as well as symplectic intergrowths.
Magnetite	1	Scattered small subhedral crystals.
Biotite	tr	Reddish-brown, slight pleochroism, small.
Apatite	tr	Small scattered rods and fibers.
Epidote	tr	Very small anhedral masses.

Remarks: Symplectic, "vermicular-like" intergrowths up to 0.2 mm in diameter, and spherulitic. Quartz xenocrysts have fine-grained corroded rims.

PLATE 6

A. Seriate texture of Patos rhyolite showing spherules of symplectic "vermicular-like" intergrowth of quartz and alkali feldspar. Plain polarized light, X 25.

B. Spherulitic symplectic "vermicular-like" intergrowths of quartz and alkali feldspar. From border zone of Patos rhyolite. Note fine-grained reaction zone around quartz xenocryst. Plain polarized light, X 25.



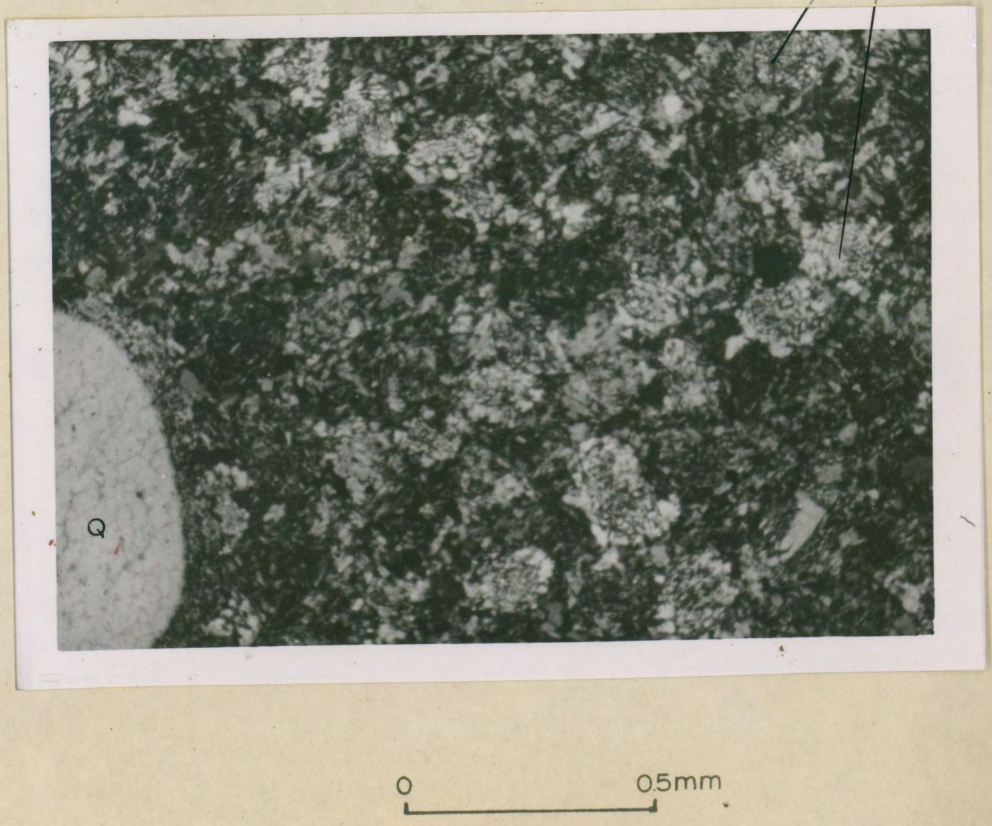


Plate 6

Sample 9-3-9

Name: Rhyolite

Texture: Holocrystalline, hypidiomorphic, seriate, subporphyritic, felty, aphanitic, aver. size = 0.1 mm.

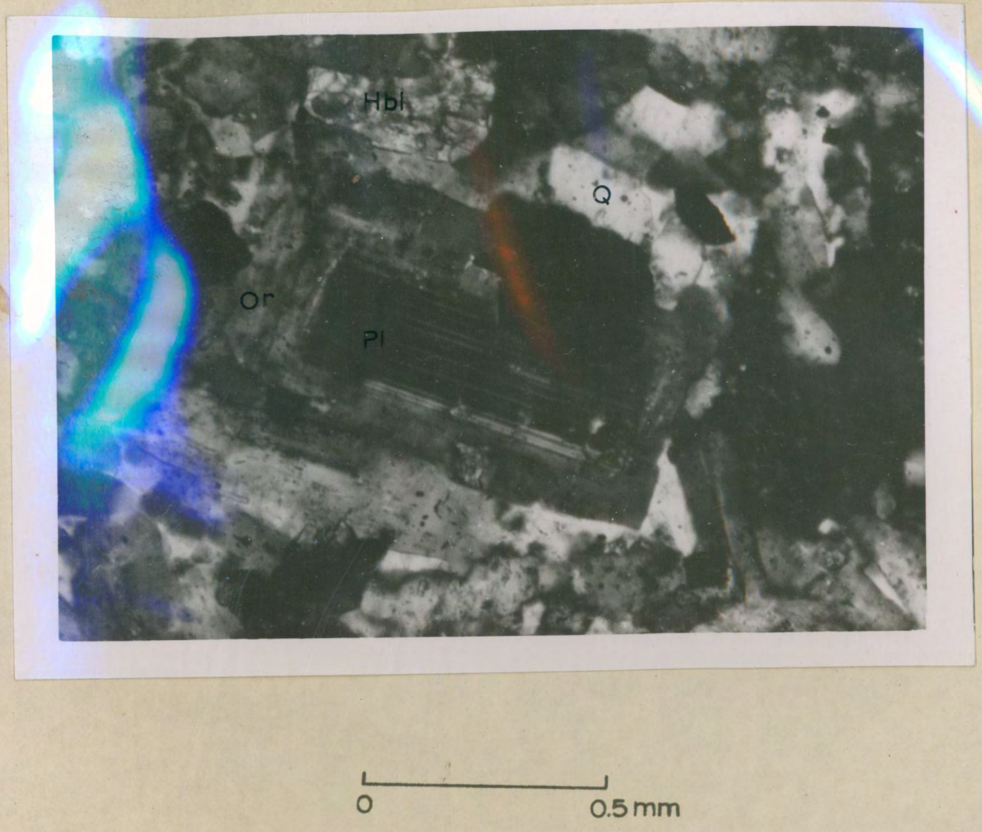
Minerals	Percent	Characteristics
Orthoclase	70	Mainly in matrix but also some overgrowths around plagioclase. Up to 3 mm long.
Quartz	20	Anhedral masses between feldspars.
Plagioclase (Ab_{70})	6	Ext. = 13°, centers of large phenocrysts overgrown by orthoclase, up to 3 mm long.
Magnetite	2	Small scattered subhedral crystals.
Biotite	1	Red, nonpleochroic.
Hornblende	1	Anhedral masses, ext. = 25°, z:c.
Apatite	tr	Very small scattered rods and fibers.

Remarks: Biotite, magnetite, and apatite occur together.

PLATE 7

A. Typical overgrowth of orthoclase over plagioclase. From microsyenite central zone of Patos laccolith. Polarized light, X 25. Note anhedral quartz.

B. Very fine perthitic intergrowth in anorthoclase (?) from central zone of Patos laccolith. Polarized light, X 640.



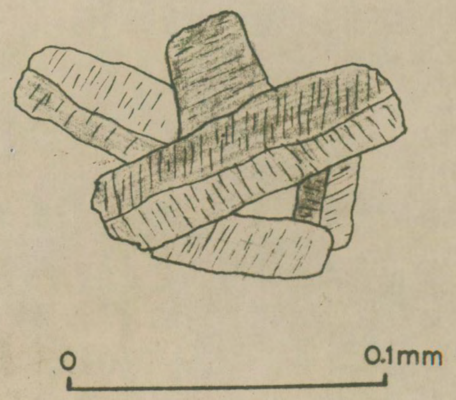
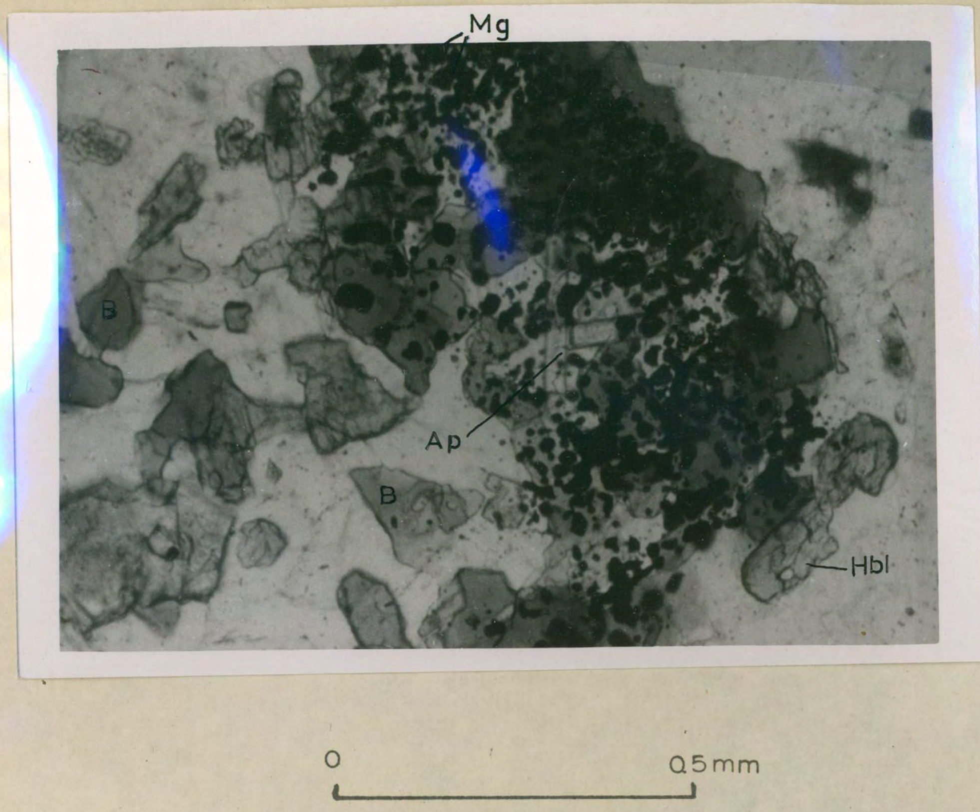


Plate 7

PLATE 8

A. Cumulophyric mass of magnetite, biotite, augite, and apatite from central zone of Patos laccolith. Polarized light, X 100.

B. Typical flow orientation of feldspars in Patos rhyolite. Joint direction is parallel to base of photograph. Polarized light, X 25.



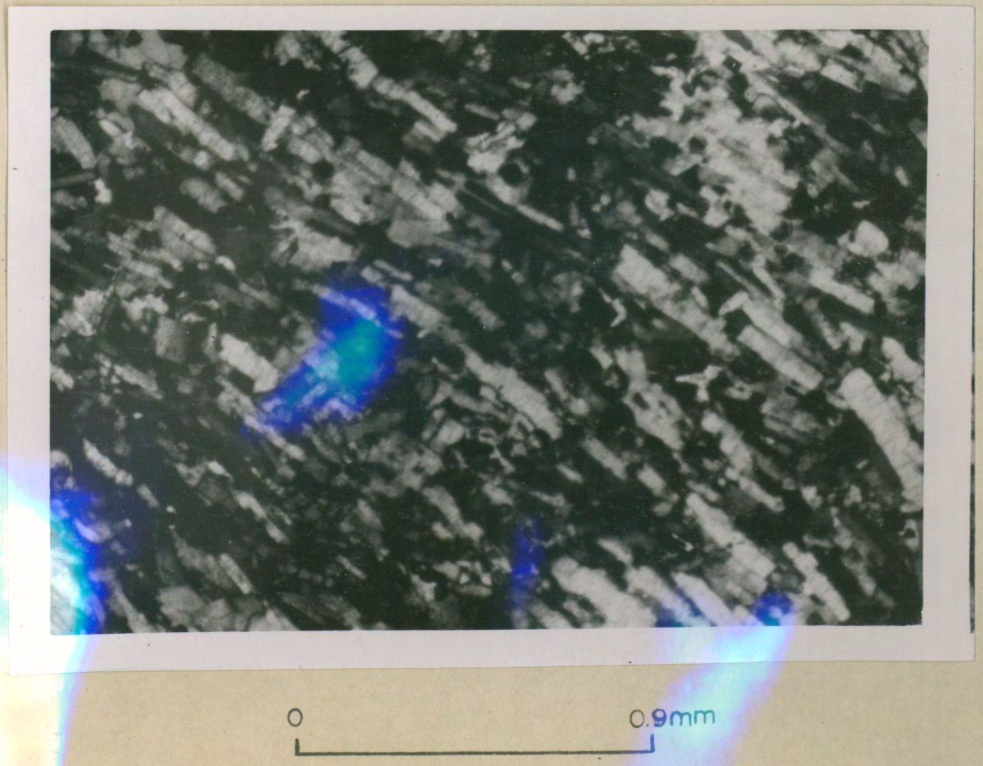


Plate 8

Sample 8-7-6

Name: Syenite (Quartz-rich)

Texture: Holocrystalline, hypidiomorphic to allotriomorphic, seriate, aphanitic porphyritic, aver. size 1/4 mm, with phenocrysts up to 2 mm.

Minerals	Percent	Characteristics
Orthoclase	72	Aver. size matrix crystals 1/4 mm. Phenocrysts up to 3 mm long. Overgrowths around plagioclase.
Plagioclase (Ab_{60-70})	10	Ext. = 18°, forms large phenocrysts with overgrowths of orthoclase.
Quartz	10	Anhedral masses between feldspar laths.
Hornblende	3	Scattered subhedral crystals, Ext. = 20°, z:c, pleochroic, light-green to brown.
Magnetite	2	Very small abundant rods and several large (1/2 mm) euhedral crystals.
Biotite	1	Very long (2 mm) crystals.
Zircon	tr	Few very small euhedral crystals.

Remarks: Clusters of hornblende, magnetite, apatite, and biotite. Some secondary quartz.

Sample 7-20-5

Name: Trachyte porphyry

Texture: Matrix less than 0.1 mm aver., phenocrysts up to 4 mm long, aphanitic porphyritic.

Minerals	Percent	Characteristics
Orthoclase (?) alkali feldspar	75	2V = 70°, phenocrysts up to 3 mm long, carlsbad twinning common.
Plagioclase (Ab_{65-75})	19	Zoning abundant, somewhat poikilitic, phenocrysts up to 3 mm, Ext. = 9°
Hornblende	2	Anhedral masses altered to limonite and epidote, ext. = 24°, z:c.
Magnetite	2	Scattered small subhedral crystals.
Biotite	1	Reddish-brown, slightly pleochroic.
Apatite	tr	Very small scattered rods and fibers.

Remarks: Feldspars altered to sericite and kaolinite; hornblende altered to limonite and epidote.

Sample 7-20-2

Name: Trachyte Porphyry

Texture: Aphanitic porphyritic, matrix less than 0.1 mm aver., phenocrysts up to 1 cm long.

Minerals	Percent	Characteristics
Sanidine and orthoclase (?)	80	Large (1 cm) phenocrysts of sanidine, 2V = 30°-40°, matrix assumed orthoclase.
Plagioclase (Ab_{70})	15	Phenocrysts up to 6 mm long, poikilitic, zoning, pericline, and albite twinning.
Biotite	2	Red-brown and brown, slightly pleochroic.
Hornblende (?)	1	Very small anhedral masses, Ext. = 20°, z:c.
Magnetite	1	Scattered euhedral to subhedral crystals.
Apatite	1	Abundant very small fibrous euhedral rods.
Sphene	tr	Euhedral crystals.

Remarks: Most of matrix altered to sericite and kaolinite. Some very thin overgrowths of orthoclase on plagioclase phenocrysts.

Sample 7-10-3

Name: Latite Porphyry

Texture: Aphanitic porphyritic, matrix < 0.1 mm aver., phenocrysts 1 to 6 mm long.

Minerals	Percent	Characteristics
Sanidine and orthoclase	58	Sanidine 2V = 30°, phenocrysts up to 6 mm long. Orthoclase in matrix only.
Plagioclase (Ab_{65})	40	Large phenocrysts, most with overgrowths of orthoclase, up to 5 mm. Pericline and albite twinning.
Biotite	1	Brown, mottled extinction, pleochroic, brown to dark-brown.
Magnetite	1	Scattered euhedral crystals.
Apatite	tr	Very small euhedral rods
Sphene	tr	Euhedral, scattered.

Remarks: Sanidine only in phenocrysts, orthoclase in matrix. Most of matrix altered to sericite and kaolinite.

Sample 6-26-2

Name: Latite Porphyry

Texture: Aphanitic porphyritic, seriate matrix and varaible phenocrysts up to 3 mm long, holocrystalline hypidiomorphic.

Minerals	Percent	Characteristics
Plagioclase (Ab_{70})	50	Ext. = 20°, Albite twinning, phenocrysts up to 3 mm.
Alkali feldspar	34	Possibly sanidine, carlsbad twinning abundant, phenocrysts up to 3 mm.
Biotite	10	Light-brown to dark-red, strongly pleochroic in light colors to nonpleochroic in dark colors, aver. 1/2 mm.
Magnetite	5	Small scattered subhedral crystals, altered to limonite.
Apatite	1	Small scattered rods and fibers.

Remarks: Feldspars altered to sericite and kaolinite, magnetite altered to limonite.

Sample 8-23-1

Name: Diabase

Texture: Diabasic to felty, holocrystalline hypidiomorphic, aver. size 0.1 mm.

Minerals	Percent	Characteristics
Plagioclase (Ab_{50})	85	Twinning abundant, long lath-shaped crystals up to 1/2 mm long.
Augite	8	Ext. = 45°, z:c, anhedral to subhedral, less than 0.2 mm aver. size, slightly pleochroic, light-green.
Quartz	3	Anhedral, filling cavities between feldspars, secondary.
Biotite	2	Reddish-Brown, pleochroic.
Magnetite	2	Scattered anhedral to subhedral, very small.
Apatite	tr	Small scattered fibers and rods.

Sample 6-28-5

Name: Diabase

Texture: Felty to diabasic, sub-ophitic, aphanitic, aver. size matrix < 0.1 mm, phenocrysts up to 7 mm.

Minerals	Percent	Characteristics
Plagioclase (Ab_{40})	75	Ext. = 33°, poikilitic phenocrysts up to 7 mm long, zoning from Ab_{40} to Ab_{80}.
Augite	20	2V = 60°, positive, Ext. = 40°, z:c, large phenocrysts up to 4 mm long.
Magnetite	3	Scattered subhedral crystals
Apatite	1	Small (0.1 mm) scattered rods and fibers.
Biotite	tr	Reddish-brown, slightly pleochroic.

Sample 6-27-2

Name: Diabase Porphyry

Texture: Holocrystalline hypidiomorphic, felty to diabasic, aphanitic porphyritic. Size range 0.1 mm to 1 mm with 1 cm phenocrysts.

Minerals	Percent	Characteristics
Plagioclase (Ab_{35})	67	Large poikilitic phenocrysts, and small laths in matrix, aver. 0.5 mm in length. Zoning common, some reaction rims.
Augite	20	Some small phenocrysts, aver. 0.2 mm, 2V = 40°, Ext. = 40°, z:c, high relief, slightly pleochroic, light-green to white. Euhedral.
Magnetite	7	Small (aver. 0.2 mm) euhedral and subhedral crystals.
Olivine	5	Scattered small phenocrysts 2V = 90°, subhedral, very high relief.
Apatite	1	Very small rods and small (0.2 mm) phenocrysts, very high relief.
Biotite	tr	Reddish-brown, slightly pleochroic, no birds-eye extinction.

Sample 6-22-4

Name: Diabase

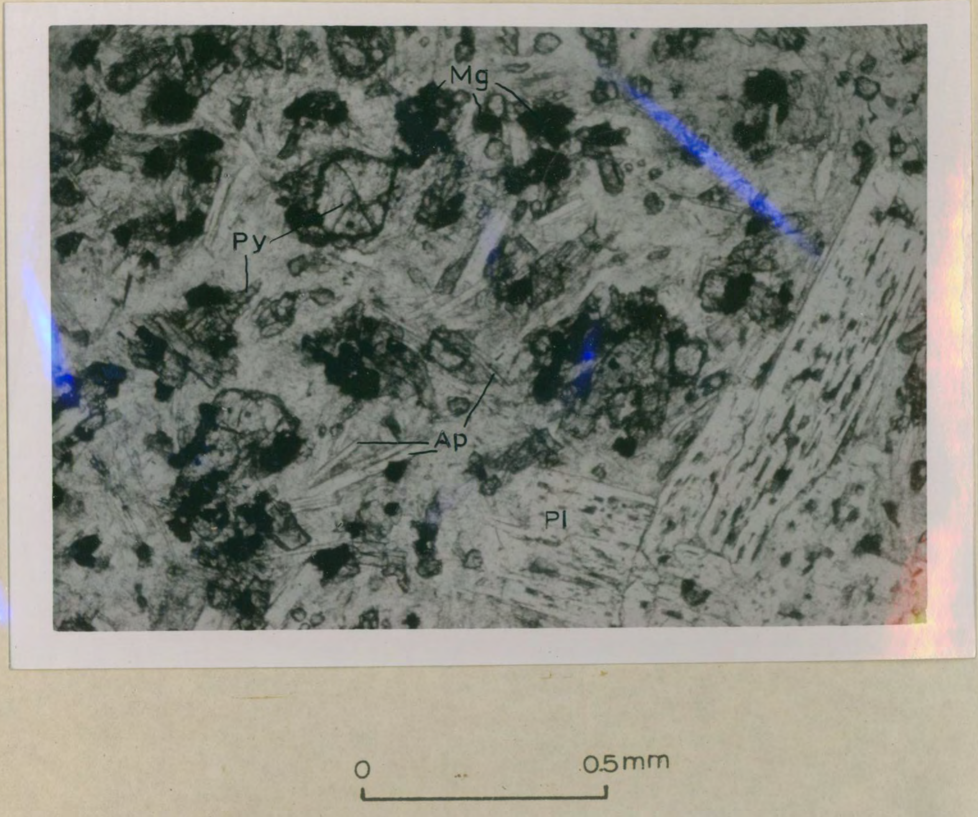
Texture: Diabasic to felty, holocrystalline hypidiomorphic, no phenocrysts, aver. size ~ 0.2 mm.

Minerals	Percent	Characteristics
Plagioclase (Ab_{80})	76	Ext. = 10°, some zoning and twinning, euhedral and subhedral laths up to 0.3 mm long.
Pyroxene (Augite)	10	Ext. = 43°, z:c, up to 0.3 mm long euhedral to subhedral.
Magnetite	6	Very small scattered subhedral crystals.
Biotite	5	Reddish-brown, nonpleochroic.
Olivine	2	Scattered white anhedral masses, very high relief.
Apatite	1	Abundant very small rods and fibers.

PLATE 9

A. Felty texture of diabase. Note poikilitic plagioclase phenocrysts and high relief of augite. Polarized light, X 25.

B. Large poikilitic phenocryst of hornblende from lamprophyre sill. Note poikilitic center and zoned border. Crossed polarizers, X 100.



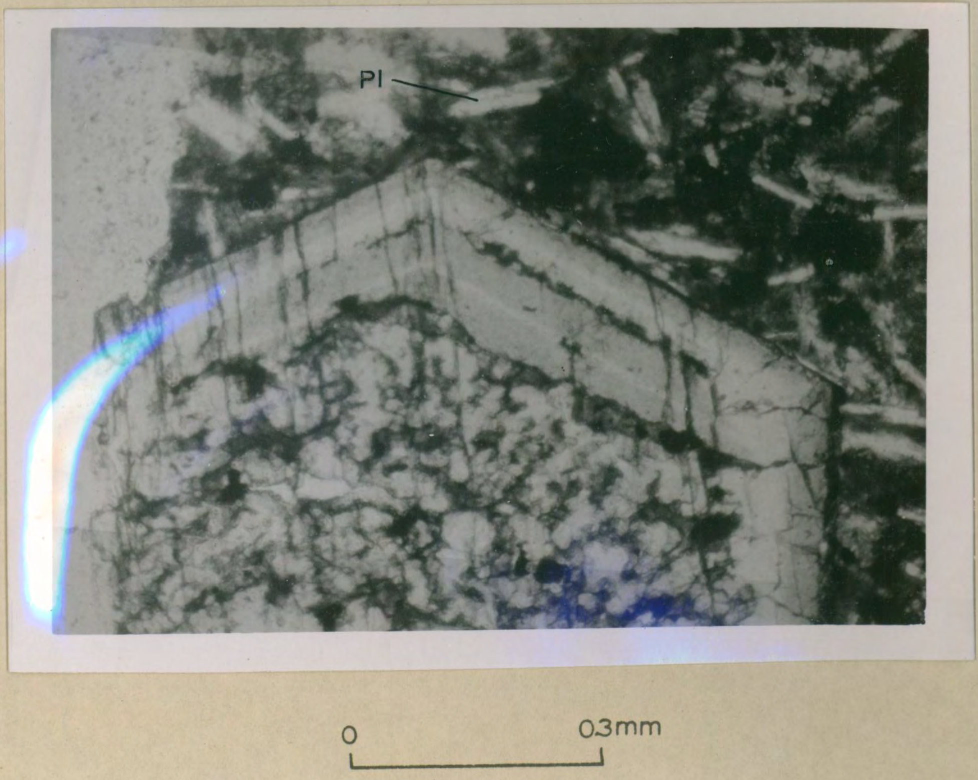


Plate 9

Sample 6-15-15

Name: Basalt Porphyry (lamprophyre)

Texture: Aphanitic prophyritic, phenocrysts up to 1 cm, felty matrix.

Minerals	Percent	Characteristics
Hornblende	40	Very large (1 cm) poikilitic phenocrysts with non-poikilitic borders. 2V = 70°. Abundant cyclic zoning and twinning.
Plagioclase (Ab_{70})	30	Long (3-4 mm) semipoikilitic laths.
Magnetite	5	Many very small subhedral crystals.
Unidentified altered matrix	25	Mostly sericite, kaolinite and carbonate.

REFERENCES

Allen, J. E., and Jones, S. M., 1951, Preliminary stratigraphic section, Capitan Quadrangle, in Capitan-Carrizozo-Chupadera Mesa region, Field trip no. 5, Roswell Geol. Soc., p. 9-11.

Bachman, G. O., 1953, Geology of a part of northwestern Mora County, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM 137.

Barth, T. F. W., 1962, Theoretical petrology: New York, John Wiley and Sons, 416 p.

Benjovsky, T. D., 1947, Contributions of New Mexico's mineral industry to World War I: New Mex. Bur. Mines and Min. Res. Bull. 27, 81 p.

Cummins, W. F., 1890, The Permian of Texas and its overlying beds: Texas Geol. Survey, 1st Ann. Rpt., p. 189.

Cross, Whitman, 1899, Description of the Telluride quadrangle, Colo.: U. S. Geol. Atlas, Folio 57.

Darton, N. H., 1922, Geologic structure of parts of New Mexico: U. S. Geol. Survey Bull. 726 E, 275 p.

Elston, W. E., and Snider, H. I., 1964, Differentiation and alkali metasomatism in a dike swarm complex and related igneous rocks near Capitan, Lincoln County, New Mexico: in New Mex. Geol. Soc., Guidebook to Ruidoso Country, 15th Field Conf. p. 140-147.

Gregory, H. E., 1916, The Navajo country: a geographic and hydrographic reconnaissance of parts of Arizona, New Mexico, and Utah: U. S. Geol. Survey Water-Supply paper 380.

Hager, Dorsey, and Robitaille, A. E., 1919, Geologic report of oil possibilities in eastern New Mexico: Unpublished report.

Havenor, K. C., 1964, Oil and gas tests in Lincoln County, New Mexico: in New Mex. Geol. Soc. Guidebook to Ruidoso Country, 15th Field Conf., p. 155-158.

Holmes, W. H., 1875, Report on the San Juan district, Colorado: U. S. Geol. and Geog. Survey Terr. (Hayden), 9th Ann. Rpt., p. 237-276.

Hunt, C. B., and others, 1953, Geology and geography of the Henry Mountains region, Utah: U. S. Geol. Survey prof. Paper 228, 234 p.

Kelley V. C., 1949, Geology and economics of New Mexico iron ore deposits: Univ. of New Mex. Pub. in Geol. no. 2, 246 p.

__________ and Furlow, J. W., 1965 Lower Palezoic wedge edges in south-central New Mexico: new control: Geol. Soc. America Bull., v. 76, p. 689-694.

__________ and Thompson, T. B., 1964, Tectonics and general geology of the Ruidoso-Carrizozo region, central New Mexico: in New Mex. Geol. Soc. Guidebook to the Ruidoso Country, 15th Field Conf., p. 110-121.

Keyes, C. R., 1915, Conspectus of the geologic formation of New Mexico: Des Moines, 12 p.

Lee, W. T., 1909, The Manzano Group in the Rio Grande Valley, New Mexico: U. S. Geol. Survey Bull. 389, 141 p.

Lindgren, W., Graton, L. C., and Gordon, C. H., 1910, The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 361 p.

Meek, F. B., and Hayden, F. B., 1862, Descriptions of new Cretaceous fossils from Nebraska Territory: Acad. Nat. Sci. Phia. Proc., 13, p. 419-420.

Needham, C. E., and Bates, R. L., 1953, Permian type sections in central New Mexico: Geol. Soc. America Bull., v. 54, p. 1653-1657.

Pray, L. C., 1961, Geology of the Sacramento Mountains escarpment, Otero County, New Mexico: New Mex. Bur. Mines Min. Res. Bull. 35, 144 p., 34 figs., 3 pls.

Rawson, D. E., 1957, The geology of the Tecolote Hills area, Lincoln County, New Mexico: Univ. New Mex. Masters Thesis, 77 p.

Rich, J. L., 1921, The stratigraphy of eastern New Mexico - a correlation: Amer. Jour. Sci., 5 th series, v. 2, p. 295-298.

Smith, C. T., 1964, Geology of the Little Black Peak quadrangle, Socorro and Lincoln Counties, New Mexico: in New Mex. Geol. Soc. Guidebook to Ruidoso Country, 15th Field Conf. p. 92-99.

Thompson, T. B., 1966, Geology of the Sierra Blanca, Lincoln and Otero Counties, New Mexico: Univ. New Mex. Dissertation, 146 p.

Travis, R. B., 1955, Classification of rocks: Quart. of Colo. Sch. Mines, v. 50, no. 1, 98 p.

Weber, R. H., 1964, Geology of the Carrizozo quadrangle, New Mexico: in New Mex. Geol. Soc. Guidebook to Ruidoso Country, 15th Field Conf., p. 100-109.

Wegemann, C. H., 1914, Geology and coal resources of the Sierra Blanca coal field, Lincoln and Otero Counties, New Mexico: U. S. Geol. Survey Bull. 541, p. 419-452.

Willmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896.

The cross sections shown below are diagrammatic - extensions of structure and intrusives below the surface are interpretive

by
Richard A Haines
1968

Figure 1: Geologic map and structure sections of the White Oaks - Patos Mountain area, Lincoln County, New Mexico