Summer 6-4-1974

Geology of the White Oaks Mining District Lincoln County, New Mexico

James R. Grainger
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87106

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Geology of the White Oaks Mining District, Lincoln County, New Mexico

James K. Grainger

Department
Geology

David A. Bamber
Department Chair

June 4, 1974

Committee

Albert H. King
Chairman

Ralph P. Landis

Paul Peterson
GEOLOGY OF THE WHITE OAKS MINING DISTRICT
LINCOLN COUNTY, NEW MEXICO

by
James R. Grainger

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
August 1974
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LINCOLN COUNTY, NEW MEXICO

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James R. Grainger

ABSTRACT OF THESIS

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ABSTRACT

The White Oak's mining district is 12 km northeast of Carrizozo, in Lincoln County, New Mexico. Hydrothermal gold and tungsten mineralization occurs in north-trending veins and breccia zones in portions of the central district.

Permian sandstones, limestones, and gypsum of the San Andres Formation are upwarped marginal to and by the Lone Mountain intrusive in the northwest portion of the map area. Triassic Santa Rosa and Chinle sandstones and shales are inclined to the south with Cretaceous Dakota, Mancos, and Mesaverde sediments. Approximately 640 m of sedimentary strata is exposed in the district.

Igneous rocks in the map area range from basalt to syenite, occurring as dikes, small discordant plutons, sills, or as part of a large stock. The oldest intrusive rock occurs in two parallel dikes of basalt. Sills and dikes of trachytic compositions intruded the sediments of the district prior to the emplacement of a syenite porphyry stock. Margins of the stock are brecciated. The roughly circular outline of the stock is modified by radiating, sinuous extensions of syenite porphyry into the surrounding sediments.
Rhyolite and intrusive rhyolite breccias occur in portions of the district. A series of small intrusive plugs and sets of short, parallel dikes outcrop in the central district. The plugs have an elongate or roughly circular shape in plan view. Dikes occur as simple dikes in sets; individual sets do not correlate with adjacent sets. Compositions include syenodiorite, trachyte porphyry, melatrachyte porphyry, trachyandesite, and mica trap.

Sediments have been altered to hornfels or quartzite at the margins of intrusives. Igneous rocks throughout the district have been highly sericitized; propylitic alteration is evident in the majority of the samples studied.

The major structural element in the district is the White Oaks Fault, a normal fault downthrown to the southeast. Regionally, the White Oaks district is on the margin of the Mescalero Arch to the east, the Claunch Sag to the west, and the Sierra Blanca Basin to the south.

The metallic minerals in the district include magnetite, hematite, pyrite, wolframite, gold, and pyrrhotite. The economic mineralization is classified as part of an epithermal ore deposit.
The White Oaks mining district as viewed from the southeast.
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INTRODUCTION

Location and Accessibility

The map area is located approximately 12 km northeast of Carrizozo, in Lincoln County, New Mexico (Fig. 1). The White Oaks mining district is included between meridians 105° 44' and 105° 47' W. longitude, and 33° 43' and 33° 47' N. latitude in T. 6 S., R. 11 E. and T. 7 S., R. 11 E. The area north of 33° 45' 50" is part of the Lincoln National Forest; the remainder of the map area is patented mining claims.

Access to the district is by State Road 349, 13 km from U. S. Highway 54 (Fig. 2). The mines are accessible by an unimproved road that crosses Baxter Gulch ½ km west of the town of White Oaks. Mine roads with limited access roads to many of the mine locations are present within the district itself. A gated ranch road provides access to the northern portion of the map area, but the western part has no vehicular access.

Physiography

Baxter Mountain (2220 m) is the physiographic apex in the district. Prominent physiographic features include Lone Mountain (2679 m), 2.7 km to the northwest, and Carrizo Peak (2943 m), 5.3 km to the southeast of Baxter Mountain.
Figure 2. Index map of New Mexico showing location of study area.
Baxter Gulch drains the central district to the south and then west, incorporating the lowest elevation of 1806 m in the extreme southwestern portion of the map area.

N. M. Fenneman (1931) and A. K. Lobeck (1948) place White Oaks in the Sacramento Section of the Basin and Range Province. Annual precipitation averages 38.9 cm per year (Pieper, 1970). Vegetation is characteristic of the upper Sonoran vegetation zone with cholla, juniper, and blue-grama as typical examples in the lower areas; pinyon and juniper dominate in the Transition or Foothills zone of Baxter Mountain and the higher ridges.

Purpose

The purpose of this study was to compile a surface geologic map of the White Oaks mining district. Emphasis was placed on the structural and petrologic elements to determine the intrusive relationships of small intrusive bodies and the enclosing sediments.

As no mineralization is exposed at the surface, a detailed petrogenesis of the ores has not been attempted.

Methods

This report is based on about 85 days of field investigation between August 1971 and January 1974. Mapping was
done on aerial photographs and on field worksheets before transferring the information to a planimetric base map with a Saltzman sketchmaster on a scale of 1:16140. From a total of approximately 115 samples, 17 samples were chosen for polished section and 37 for thin section petrographic study. All modal analyses given are based on visual estimates of mineral percentages.

Previous Investigations

Very little geologic mapping has been done in White Oaks mining district. Jones (1905) published a N.E.-S.W. section through the district that he sketched on February 6, 1904 while standing at the shale contact near the Old Abe mine. Graton visited the district in 1905. His report on the mining activity with some petrographic observations was published with Lindgren and others (1910). As a part of a description of mineral deposits in Lincoln County, Griswold (1959) included a summary of the mining history with subsurface maps of some mines and a plane table map of the South Homestake workings. Students from the New Mexico Institute of Mining and Technology, under the supervision of Clay T. Smith, compiled a geologic reconnaissance map of the Little Black Peak 15-minute quadrangle that included parts of the district (Smith, 1964). Recent investigations
by R. H. Jahns and others have remained unpublished, as have numerous investigations conducted for economic concerns.

Acknowledgments

I would like to express my thanks to Dr. V. C. Kelley for suggesting the area of study. I most especially wish to thank Dr. A. M. Kudo for giving of his time for trips in the field, for his advice, and for his assistance at the microscope.

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I am also grateful to the ranchers and property owners of White Oaks, especially Owen H. Simpson and Bud Crenshaw, for their assistance and cooperation.
ROCK UNITS

Approximately 640 m of sedimentary strata is exposed in the White Oaks district. The actual stratigraphic accumulation cannot be measured accurately because intrusive dikes and sills have disturbed the sequence so that the apparent thicknesses in the section are well beyond the narrow limits defined by authors working elsewhere in the area (Smith, 1964; Ryberg, 1968; and Haines, 1968).

The sedimentary rocks range from Permian to Upper Cretaceous in age and include both continental and marine deposits. The oldest sedimentary rock in the district is in the San Andres Formation; the youngest is in the lower Mesaverde Formation. The Permian sediments have been grouped as San Andres Formation for this study.

Permian System

San Andres Formation

The San Andres Formation was named by Lee (1909) for exposures in the San Andres Mountains of south-central New Mexico. At the type locality, the formation is 183 m thick, but the upper part has been removed by recent erosion. Kottlowski and others (1956) reported 198 to 213 m of San Andres from oil tests in the same area and Allen (1951)
reported the formation to be 213 m thick in the area of Capitan in Lincoln County.

In many areas of the state, the San Andres is divided into a lower sandstone member corresponding to the Glorieta Sandstone, a middle limestone member distinguished as an intermediate unit, and an upper reddish sandstone and gypsum member corresponding to the Chalk Bluff Formation (Allen, 1951) and the Whitehorse Group of Bates (1942).

In the White Oaks district, the San Andres is exposed on the southeast slope of the Lone Mountain intrusive (Fig. 3). The lower contact of the San Andres is an intrusive contact with the igneous rock of the Lone Mountain stock, which has been variously reported as kalialaskite (Butler, 1964), normarkite (Smith, 1964), and syenite (Budding, 1964). A small exposure of a fine-grained, buff, quartz sandstone, weathering reddish brown, is in place near the contact.

The middle limestone facies provides the best exposures of the San Andres Formation. The rock is blue grey to dark grey, fine grained, thick bedded, and only rarely fossiliferous. Figures 4 and 5 illustrate the representative fossils; a scarcity of specimens prevented definitive classification.
Figure 3. San Andres Limestone (foreground) dipping away from the flank of Lone Mountain (background).

Figure 4. Coiled nautiloid (Doratoceras sp.?) in San Andres Limestone (Permian).
Figure 5. Permian fusulinids from the San Andres Formation.

Figure 6. Weathered surface of gypsum (upper San Andres Formation) illustrating pseudokarren surface. A 15 cm scale included in the foreground.
Near the upper contact, the San Andres limestones are interbedded with and overlain by a gypsum facies. The gypsum is white on fresh surfaces with yellow limonite staining in some parts, and weathers to a light-grey, pseudokarren textured surface (Fig. 6).

Triassic System

Santa Rosa Formation

The contact between the Permian and Triassic is obscured by an intrusive dike that generally parallels the strike of the Santa Rosa. The formation was named by Darton in 1919. The type locality is quoted from Darton (1922) as "...prominent in mesas of Guadalupe County along the Pecos River at Santa Rosa". Darton does not give a thickness for the unit.

In the White Oaks district, the Santa Rosa Formation (Fig. 7) is poorly exposed and appears to have been disrupted by intrusives. The rock is dark-reddish-brown, micaceous, quartz sandstone and siltstone. The Santa Rosa Formation is 52 m thick in the Jicarilla area (Nyberg, 1968), 76 m in the Patos Mountain area (Haines, 1968), 90 m in the Carrizo Quadrangle (Weber, 1964), and an average of 61 m in the Little Black Peak quadrangle (Smith, 1964).
Figure 7. Santa Rosa Formation. View to the northeast.

Figure 8. Valley forming Chinle Shale (Triassic) center of view to the west. Dakota Fm. (Kd), Chinle Fm. (Trc), Santa Rosa Fm. (Trsr), Tertiary intrusives (Ti).
Chinle Formation

The Chinle Shale overlies the Santa Rosa gradationally and is reported as a thin-bedded, red to purple shale and siltstone with several pebble-conglomerate lenses and some interbedded red to brown sandstones. The formation was first described by Gregory (1916) from exposures in the Chinle Valley of northern Arizona.

In the map area, the Chinle Formation (Fig. 8) forms broad valleys between the more resistant Dakota and Santa Rosa sandstones. The non-micaceous, reddish-brown, quartz sandstones are the only rocks of Chinle age well exposed in the White Oaks district. Variegated shales are exposed between closely spaced dikes at one location. Soils formed on the shales have a lavender to very dark red color, with the best example in the northeast sector.

Cretaceous System

Dakota Formation

An unconformity separates the Chinle from the overlying Dakota Sandstone. The formation was first described by Meek and Hayden (1862) from exposures in Dakota County, Nebraska. In the White Oaks area, the basal sand of the upper Cretaceous is referred to as the Dakota Formation. Between 46 and 61 m of Dakota Formation has been reported in the White Oaks area (Smith, 1964; Haino, 1968).
The Dakota Sandstone in the map area is a distinctive ridge-forming, clean, well-sorted, massive, buff-colored, medium-grained, quartz sandstone that weathers with a grey to black surface (Fig. 8). In some specimens, limonite cement is present and in many areas limonite and hematite solution banding is common. Marginal to intrusive bodies, the Dakota Sandstone is more quartzitic in character and occasionally encloses grains and pockets of pyrite.

Mancos Shale

The Mancos Shale was named by Cross (1899) from exposures near Mancos, Colorado. The formation overlies the Dakota gradationally and is widespread throughout the district. Between 183 m and 214 m of Mancos Shale is exposed in the district (Fig. 9).

The Mancos Shale is a laminated, lenticular, black to greenish-grey shale interbedded with a single thick-bedded, black, fine-grained, nonfossiliferous limestone and three, very thick bedded sandstone units. The formation is the most extensive sedimentary unit in the district and is altered to hornfels in the central district near contacts with the intrusive rocks.
Figure 9. Typical outcrop of Mancos Shales (Cretaceous) with dikes and sills of trachyte. View to the north from Baxter Gulch.

Figure 10. Mesaverde Formation from the southern part of the map area.
Mesaverde Formation

The Mesaverde Formation was first described by Holmes (1877) from exposures near Mesa Verde in southwestern Colorado. In the lower part, it is a nonmarine sandstone with small interlayered shale units gradationally overlying Mancos Shale. The sandstone rock is well sorted, massive, buff to light-grey in color, and weathers to a light brown or black color at the surface. The black and grey shales of the Mesaverde Formation are poorly exposed in the district.

Mesaverde sandstone caps Baxter Peak and is best exposed in the southern portions of the district (Fig. 10). Pelecypod molds (Inoceramus sp.) and worm burrows are occasionally seen in some areas.

Quaternary Deposits

Deposits of Quaternary materials in the White Oaks district include alluvial valley fill, landslide debris, and slope debris.

Landslide Deposits

Landslide debris is predominant in the southeast sector of the map area. Baxter Gulch defines the northern and western limit of Quaternary deposits derived from Carrizo Peak (Fig. 11). The debris consists of unconsolidated,
Figure 11. Aerial view from Carrizo Peak to the northeast showing Quaternary landslide deposits at the base of Baxter Mountain outlined (Q1s).

Figure 12. Slump blocks in Mancos Shale along Baxter Gulch.
angular fragments and mixed soils. On the west slope of Baxter Mountain, landslide debris consisting mostly of Mesaverde Sandstone are common. A series of six small, semicircular terracettes on the upper, steeper slopes are possibly small slump blocks. Two smaller slump features are mapped along Baxter Gulch. The cap is a trachyte sill and the body of the slump blocks is Mancos Shale (Fig. 12).

Slope Debris

Scree deposits mantle the ridges and slopes of the central district. The debris consists of mixed soils and angular igneous rock fragments. It is not mapped as a separate unit because it overlies similar consolidated rock at depths of less than a meter in the upper valley bottoms to 5 m. on ridges and hillsides. Scree is the biggest single detriment to precise geologic mapping and economic exploration in the district.

Alluvium

The larger, gently sloping valleys are floored with alluvial soils basically derived from nearby rocks. The underlying source rock is less commonly represented, indicating some degree of transport (Fig. 13).

Figure 1 also designates more recent tailings deposits derived from milling operations in the district.
Figure 13. Alluvium in gently sloping valleys (light yellow) in view to the northeast.
Figure 13. Alluvium in gently sloping valleys (light yellow) in view to the northeast.
IGNEOUS ROCKS

The type of igneous rocks in the map area ranges from basalt to syenite, occurring in dikes, small discordant plutons, and sills, or as part of a large stock. The predominant igneous rock type is trachyte porphyry. Propylitic alteration is widespread; the most common secondary minerals are calcite, epidote, muscovite, pyrite, hematite, and chlorite.

The igneous rocks are subdivided in this report in accordance with age sequence and with corresponding compositions.

Basalt Porphyry Dikes

The oldest intrusive rock in the White Oaks district is in two contemporaneous, parallel dikes exposed on the southwest margin of the map area. Both dikes are composed of basalt porphyry with platy phenocrysts of plagioclase (An$_{60-62}$) that weathers white in contrast with the olive-green colored groundmass containing olivine and augite microphenocrysts with feldspar plagioclase feldspars (An$_{46-49}$). The plagioclase phenocrysts average 1 cm in length and are roughly oriented parallel with the vertical dike margins, trending N. 15° E. (Fig. 14).
One of the two dikes is a mappable unit 5 m wide, with an exposed length of 3 km. The southern continuation is covered by alluvial soils. The extension in the other direction terminates at the margin of a trachyte stock near the center of the district. A similar dike, with approximately the same orientation, is exposed in Dakota Sandstone on the other side of the stock in the northeast quadrant of the map area.

An olivine-augite basalt porphyry dike rock is also exposed in Dakota Sandstone and Mancos Shale from the northeast quadrant of the mapped area. The surface exposure is poor and the relative age is uncertain. The rock is black and has a porphyritic character best observed on the light-brown weathered surface. Normally zoned, euhedral, slightly titaniferous augite phenocrysts are enclosed in a fine-grained olivine-augite-magnetite-plagioclase groundmass (Fig. 15). An occasional labradorite phenocryst (An$_{62-70}$) may be present. The texture is panidiomorphic granular (Williams and others, 1954).

**Trachyte Sills and Dikes**

A group of sills and dikes of trachytic composition is intruded into the sediments throughout the district. Sills (Fig. 16) are concordant, nearly horizontal structures,
Figure 14. Plagioclase phenocrysts in a basalt porphyry dike of the southwest sector.

Figure 15. Olivine-augite basalt porphyry, a dike rock in Dakota Sandstone, northeast sector. Olivine (Ol), Augite (Aug), Plagioclase (Pl). Crossed nicols.
generally less than 9 m thick. The best exposures are in Baxter Gulch where the trachyte is in Mancos Shale. In hand specimen, the rock is fine grained, pinkish grey to yellow, and porphyritic in the central portions of the intrusive structures. The trachyte porphyry is composed of orthoclase and microcline phenocrysts in a fine-grained, felted-feldspar groundmass with biotite, apatite, and magnetite. Secondary minerals include calcite, epidote, chlorite, and muscovite.

Narrow dikes (less than 1 m thick) connect sill bodies in some areas (Fig. 24). Larger (1-3 m) dikes, with essentially the same composition as the sills are found to be discordant to both sills and adjacent sediments (Fig. 17). Similar compositions of dikes and sills indicate a common source, while the structural relations define a slight difference in the ages of emplacement.

Trachyte sill and dike margins are irregular in the Mancos Shale, and the dikes in shales and sandstones generally have sinuous traces (Fig. 9). Sills are intruded at various levels in the Mancos Shale; for example, on the southeastern slope of Baxter Mountain.
Figure 16. Tertiary intrusive trachyte sill (Tt) in Mancos Shale, capped by Carrizo Peak landslide debris, in Baxter Gulch.

Figure 17. Trachyte dike crosscutting Mancos Shale and trachyte sill in Baxter Gulch (hammer at center of photo for scale).
Rhyolite and Rhyolite Flow Breccia

Rhyolite and intrusive rhyolite breccias occur in two areas on the fringes of the White Oaks district. The breccia is the best exposed and incorporates pyritic limestone fragments and sandstone fragments up to 2 m in length. The rhyolite is aphyric in hand specimen. Corroded, altered phenocrysts (0.5-1.4 mm) are rare and occur in a granular feldspar-quartz groundmass. An opaque mineral determined to be hematite after magnetite averages 12 percent of the rock. Flow texture is not evident microscopically, but is distinctive in outcrops of rhyolite plugs and dikes (Fig. 18).

Main Intrusive Mass

Trachyte-syenite Porphyry Stock

A trachyte-syenite porphyry stock has intruded the central part of the district and exhibits an irregular outline modified by dike-like extensions into surrounding sediments (Fig. 1).

At the stock margin, an intrusive breccia incorporates angular to subrounded sedimentary fragments. Locally, the enclosed fragments are predominantly of one sedimentary group, usually the adjacent or underlying formation. The breccia containing Chinle shale and sandstone fragments is distinctive. Reddish-brown sandstone and shale fragments
Figure 18. Rhyolite flow breccia from a dike in Chinle Shale of the northwest sector.

Figure 19. Approximate outline of a centrally located stock in the White Oaks district. View to the southeast with Carrizo Peak in the background.
are enclosed in a greenish-gray, aphanitic groundmass with disseminated, black specularite. Where the Chinle Formation is exposed near the intrusive contact, brecciated sandstones will occasionally have cavities lined with quartz and filled with specularite.

On the east and southwest margins of the stock (Fig. 19), breccias with Mancos Shale fragments predominate; in the northeast, limestone fragments are more common. Micro-inclusions of igneous rocks are present in addition to the sedimentary fragments.

Inside the marginal area of the trachyte stock, the rock is more porphyritic and vesicular, possibly indicating a shallow, hypabyssal origin. The color of the rock is pinkish brown, weathering to brown. Orthoclase phenocrysts average 0.5 mm, are grey, and weather flush with the rock surface. When altered, this same rock is yellow (Fig. 20) and the color of the rectangular phenocrysts changes progressively from tan to white with increasing alteration.

In the central portion of the stock, the rock is more porphyritic with larger phenocrysts of orthoclase and microcline; individual euhedral crystals 2 cm in length are not uncommon. The rock is classified as a syenite porphyry. Apatite and sphene are common accessory minerals in a
Figure 20. Weathered surface of syenite porphyry.

Figure 21. Microscopic view of syenite porphyry from the centrally located stock. Microcline (Mi), orthoclase (Or), sphene (Sp) replaced by calcite (Cal). Crossed nicols.
quartz-free, fine-grained, granular-feldspar groundmass.

The opaque mineral is magnetite, consistently replaced by hematite. The approximate modal composition is as follows:

- 56% Sanidine and Orthoclase
- 15% Microcline
- 4% Magnetite
- 2% Hornblende
- 1% Biotite
- tr Sphene
- tr Apatite
- 21% Indeterminate groundmass

Sanidine phenocrysts are large (up to 6.1 mm) and poikilitically enclose small crystals of microcline (0.51 to 0.69 mm). Microcline and orthoclase both occur as phenocrysts, the microcline occasionally having an over-growth of orthoclase. The feldspars are highly sericitized, the hornblende is altered to clinozoisite, and the biotite is rimmed with chlorite (Fig. 21).

Structurally, the stock appears to have vertical margins and a generally circular shape in plan view. Part of the irregular outline is due to modification by dike-like extensions of syenite-trachyte porphyry into the surrounding sediments. Along the surface, the dikes have sinuous traces roughly radiating away from the central stock. The dikes typically lack brecciated margins, but do have wide chill zones. The distinctive characteristic of these dikes is the width, exceeding 200 m near the stock and narrowing to 50 m
at blunt terminations of their farthest extensions into the country rock.

Small Intrusive Plugs and Dikes

A series of small intrusive plugs and sets of short, parallel dikes outcrop in the central district. The plugs have an elongate or roughly circular shape in plan view, averaging less than 100 m in length and 50 m in width. The dikes are generally less than 100 m long and 5 m wide, occurring as simple dikes in sets. Dike sets lack a common orientation. Exposures of both dikes and plugs indicate steeply dipping margins (Fig. 52, in pocket).

Syenodiorite

Small elongate plugs of syenodiorite are intruded in the central part of the district. This may be the rock that has been referred to in previous works as monzonite. The best exposure is between the North Homestake shaft and the Lady Godiva workings (Fig. 22). The surface outcrop is small, 120 m in the longest dimension. In hand specimen, the rock is medium grained, light grey, with phenocrysts of plagioclase and alkali feldspar (Fig. 23). The average modal composition is as follows:
Figure 22. Location map for the major mines in the White Oaks district.
Figure 23. Surface outcrop of syenodiorite plug.

Figure 24. Syenodiorite with clusters of ferromagnesian minerals (C) and plagioclase phenocrysts (P1).
70% Plagioclase (An<sub>43</sub>)
20% Orthoclase
3% Magnetite
2% Hornblende
2% Biotite
2% Apatite
tr Sphene

The plagioclase forms bostonitic texture and the
ferromagnesian minerals are clustered with apatite and
magnetite (Fig. 24). Large grains of subhedral orthoclase
poikilitically enclose plagioclase grains. Skeletal magne-
tite is very distinctive in thin section.

Mica Trap

Mica Trap was first described in the White Oaks district
by Griswold (1959) from exposures on the South Homestake
property. In hand specimen, the rock is a friable, mica-
ceous, black specimen with small, spherical infilled
cavities (Fig. 25). In thin section, the rock is a mixture
of rimmed olivine, augite, and biotite poikilitically
enclosed in anorthoclase. The spheroidal cavities are
filled with subhedral analcime and natrolite. The average
modal composition may be represented as follows:

25% Anorthoclase
35% Augite
20% Biotite
15% Olivine
3% Analcime

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Figure 25. Outcrop of mica trap exposed on the crest of the ridge between the South Homestake and the North Homestake mines, cut by two trachyte dikes left and right center.

Figure 26. Trachyte porphyry dike emplaced in syenodiorite.
The main opaque mineral is magnetite; traces of chalcopyrite, pyrite, and hematite after magnetite are present. There may be other copper sulphides associated with the chalcopyrite, but the grains are too small for a definitive determination in polished section. Other secondary minerals include calcite and clinozoisite. The rock may be classified as olivine melasyenite.

Trachyte

Small plugs and dikes of trachyte composition intrude syenodiorite, syenite porphyry, and sediments of the White Oaks district. An example is taken from an exposure between the North Homestake shaft and the Lady Godiva shaft; from a dike that has intruded syenodiorite (Fig. 26). Some dikes have chilled margins.

The rock is tan to light brown in hand specimen, weathering to a dark-brown, pitted surface. Alkali feldspar phenocrysts (2-3 mm) are enclosed in an aphanitic groundmass. Microscopically, the texture of the groundmass is trachytic. Felted feldspars enclose phenocrysts of orthoclase and microcline (0.6-5.6 mm) and occasionally plagioclase (An₃₄).
The only accessory minerals are apatite and biotite. Secondary minerals include muscovite, epidote, and calcite. The opaque mineral is hematite after magnetite, with trails of pyrite.

**Trachyte Porphyry Transitional Group**

A group of dike rocks is distinguished in the field and microscopically by transitional compositions intermediate to the trachyte porphyries just described and the following melatrichyte-andesite group. The intermediate trachyte porphyries are represented in exposures of two dikes in Baxter Gulch in the southeastern portion of the district. One of these two dikes is characterized by phenocrysts of alkali feldspar that average between 2 and 4 cm in length (Fig. 27). Hand specimen color is dark grey to pinkish grey. Poikilitic phenocrysts of orthoclase are present in an aphanitic, felted feldspar groundmass with accessory biotite, apatite, hornblende, sphene, and microcline (Fig. 28). Rocks of this intermediate group are classified as trachyte porphyries.

**Melatrichyte and Andesite Compositions**

Melatrichyte and andesite intrusives as small plugs characterize one of the most distinctive groups of rocks in the district. The rock in hand specimen appears to be
Figure 27. Transitional trachyte porphyry dike (dark grey) cutting a trachyte sill in Mancos Shale (black).

Figure 28. Propylitically altered intermediate trachyte porphyry with impressions of plucked alkali feldspar. Specimen from Baxter Gulch.
unaltered, with hornblende or augite or biotite phenocrysts, and with a characteristic blue-grey color (most other rocks in the area have yellow-brown colors).

The best exposures are small, elongate pods on the east slope of the South Homestake ridge, in the saddle between the Little Mac and the Lady Godiva workings, and in the drainage south of the Old Abe (Fig. 22). The rock in each example is unique microscopically, but all appear to be the same rock type in hand specimen. Mineralogical classifications are based on compositions as determined microscopically. As a group, the rocks of this series are a bluish, light-grey to dark-grey color in hand specimen. The rock weathers to a brownish, blue-grey color on the surface of the less altered specimens and is greenish-grey to olive-green rock in the highly altered varieties. The groundmass is aphanitic and encloses large phenocrysts of hornblende, augite, or biotite with smaller (2-6 mm) phenocrysts of alkali feldspars (Fig. 29).

At the Old Abe location, rimmed microcline phenocrysts predominate; no hornblende was observed in thin section. The average modal composition is as follows:

56% Microcline
12% Augite
8% Biotite
4% Apatite
Figure 29. Melatraghyte porphyry from a surface outcrop near the South Homestake shaft. Hornblende (Hb), Feldspar (Fs), Augite (Aug), Biotite (Bio). Plane light.

Figure 30. Surface outcrop of melatraghyte porphyry on the east-facing slope of the South Homestake ridge.
3% Magnetite
tr Sphene
16% Indeterminate groundmass

The microcline is occasionally rimmed with anorthoclase and chlorite rimz are found on biotite. Glomeroporphyritic best describes the texture. The rock is mineralogically classified as a melatlache porphyry.

In the outcrop near the South Homestake shaft, zoned, idiomorphic, hornblende phenocrysts predominate in size over idiomorphic, zoned, crystals of augite with seriate textures. Rimmed microcline occurs as phenocrysts with accessory biotite, apatite, and sphene in a felted feldspar and magnetite mesostasis. The average modal composition is as follows:

28% Microcline
21% Augite
18% Hornblende
12% Orthoclase
4% Magnetite
3% Biotite
tr Apatite
tr Sphene
13% Indeterminate groundmass

Trachytic texture predominates in the groundmass; panidiomorphic-granular or lamprophyric textures may also apply to this sample (Turner and others, 1954). The rock is best described as a melatlache porphyry (Fig. 30).

At the location in the saddle between the Little Mac and the central district, plagioclase is the dominant
feldspar. The rock is classified as a trachyandesite porphyry. The average modal composition is as follows:

- 33% Plagioclase (An47)
- 27% Augite
- 16% Hornblende
- 6% Magnetite
- 4% Microcline
- tr Biotite
- tr Sphene
- 13% Indeterminate groundmass

The augite has a seriate texture and hornblende forms phenocrysts as large as 7 cm (Fig. 31). Small, rounded grains of serpentinized olivine are present in the groundmass. Microcline is present in occasional phenocrysts measuring between 0.2 and 0.7 mm in the long dimension.

A typical exposure of the rocks in this group is represented by the South Homestake location where the age relationships are determined from the structural contacts in the field and from the composition of xenoliths. Shale, limestone, sandstone, trachyte, and syenodiorite xenoliths are illustrated in Figure 32. Although rocks of this group appear to be unaltered in hand specimen, microscopic examination shows that the feldspars are sericitized and other secondary minerals are as common as in other rocks in the district.
Figure 31. Hornblende megaphenocrysts in trachyandesite, from the Little Mac location (p. 37).

Figure 32. Xenoliths in melatbrachyte porphyry, from the east slope of the South Homestake ridge. Shale (Sh), Sandstone (Ss), Limestone (Ls), Trachyte (Tra), Syenodiorite (Sd), Hornblende (Hb).
Breccia Masses

There are two small but distinctive breccia masses in the central district. Both are poorly exposed, with covered margins. Because of their proximity to individual mines, they are referred to as the Old Abe breccia and the Lady Godiva breccia, respectively.

The Old Abe breccia (Fig. 33), west and north of the Old Abe shaft, is a light-grey breccia composed almost entirely of angular trachyte fragments; sedimentary fragments are less common. The breccia has no matrix; the open space between fragments is lined with crystalline quartz and an occasional pyrite dodecahedron. Banded hematite also lines some open cavities. Pyrite is replaced by hematite, goethite, and lepidocrocite (Fig. 34). Calcite and hematite are vein minerals in this rock. Pyrite is rare in veins, occurring as small, relic blebs enclosed by hematite (Fig. 35).

The Lady Godiva breccia is an intrusive breccia related to the emplacement of plugs and dikes in the immediate area of the Lady Godiva shaft. Angular fragments of rock containing feldspar microlites predominate over smaller and less numerous shale fragments in a biotite-feldspar matrix. The rock is dark grey, the groundmass is aphanitic, and pyrite is very common in hand specimen. Microscopically,
Figure 33. Old Abe breccia outcropping just south of the Fish Pond on the Old Abe property. Andesite dike left and far right.

Figure 34. Pyrite from the Old Abe breccia replaced by hematite, goethite, and lepidocrocite. Crossed nicols in reflected light.
the opaque minerals are found to be restricted to the matrix, with pyrite and magnetite in approximately equal proportions. Only a trace of hematite is present. Secondary minerals include calcite and biotite.

The Lady Godiva breccia is veined by quartz, pyrite, gypsum, arsenopyrite, and manganese and iron oxides. Gypsum with pyrite forms the larger veins (Fig. 36). An occurrence of virgin gold in gypsum has been reported (Jones, 1905) from the Old Abe mine.

Trachyandesite and Andesite

Trachyandesite and andesite are represented in the district as dike rocks. In hand specimen, the rock is aphanitic, equigranular, and light grey. Biotite may form as much as 30 percent of the rock. An occasional orthoclase phenocryst may be present, but plagioclase feldspars are predominant. Accessory minerals include augite, olivine, biotite, sphene, and apatite. The opaque minerals are pyrite and hematite, both of which may be secondary along with chlorite, calcite, clinozoisite, and epidote.

Exposures of rocks in this group are rare; the rock is highly altered and easily eroded. The best outcrop in the map area is just south of the Fish Pond on the Old Abe property (Fig. 33).
Figure 35. Pyrite blebs enclosed in hematite. Sample from the Old Abe breccia. Plane reflected light.

Figure 36. Gypsum veins (white) in the Lady Godiva breccia at the Lady Godiva shaft collar (right).
ALTERATION

With the exception of a single dike, all of the samples of igneous rocks studied in thin section show extensive alteration. Alteration of sediments marginal to intrusives is more apparent in parts of the central district. Wall rock alteration adjacent to outlying dikes and sills is minimal; bleaching of shales is the only significant wall rock alteration outside the central district.

Alteration of Sediments

Sediments at contact with intrusives have been altered to hornfels or quartzites in parts of the central district. Mancos Shale is the most common sedimentary group in the area and hornfels are the most common altered rock (Fig. 38). Sandstones, where exposed near intrusive contacts, have been altered to a reddish-brown quartzite. A limestone bed within the Mancos Formation is silicified.

At one location in Mancos Shale between the Iron Cap mine and the Old Abe property, (foreground in Fig. 36), there are indications of extensive thermal metamorphism. Thin sections and X-ray methods were necessary to identify scapolite and axinite, associated with radiating clusters of diopside and actinolite with oolitic calcite. The associated metallic
Figure 37. Central district of the White Oaks mining camp. Baxter Mountain left center. View to the southwest.

Figure 38. An example of hornfels from the central district.
mineral is pyrrhotite, occurring as small, irregular, disseminated grains (Fig. 39).

In areas outside the central district, sandstones and shales marginal to intrusives appear to be unaffected by contact metamorphism. A narrow bleached zone a few centimeters wide in a shale host rock is the only alteration observed.

Alteration of Igneous Rock

Sericitization

Sericitization is the dominant alteration effect observed in most of the specimens studied. The alkali feldspars and plagioclases appear to have been affected to about the same degree. Because approximately the same degree of sericitization of the feldspar minerals is encountered in similar rock types outside the district, it may be assumed that a proportion of the alteration of the igneous rocks of the White Oaks district is deuteric. The only comparatively unaffected mineral in the samples studied is apatite; the only visible effect of alteration on the mineral is a brown stain (Fig. 40) in the more highly altered specimens. Figure 40 illustrates the degree of alteration in the interstitial feldspar grains and the large feldspar phenocryst when viewed in plane light.
Figure 39. Pyrhotite grain in altered Mancos Shale of the central district. Plane reflected light.

Figure 40. Brown-stained apatite crystals (right) with a single feldspar phenocryst (upper left) in highly altered trachyte porphyry dike rock. Plane light.
Propylitization

Propylitic alteration, as defined by Creasey (1966), is evident in the majority of the samples studied. The degree of alteration varies with the rock type. Characteristic minerals of this alteration phase include calcite, epidote, pyrite, and chlorite.

Chlorite replaced or rims the fero-magnesian minerals and, less commonly, the feldspar. Chlorite generally is fine grained and restricted to the individual minerals it replaces.

Epidote is a widespread alteration product, usually interstitial, occasionally growing into open cavities (Fig. 41). The mineral is essentially restricted to the trachyte and andesite rock types.

Calcite is the most common alteration product, replacing individual minerals and filling open spaces in vesicles or veins. Calcite is most often found in trachyte and rhyolite rocks throughout the district.

Pyrite is the least common of the propylitic alteration minerals, but is found in all but the basaltic rocks of the district. Pyrite forms as isolated, large pyrite-hedrons in vesicles in some trachyte dikes (Fig. 41), in open spaces of the Old Abe breccia, and associated with gypsum in veins.
Figure 41. Epidote crystals growing into an open cavity in trachyte porphyry. Crossed nicols.

Figure 42. Calcite (Cc), pyrite (Py), and quartz (Qtz) in vesicles within trachyte porphyry dike rock from Baxter Gulch.
on the surface at the Lady Godiva property. Small interstitial grains of pyrite are less frequent in other rock types.

Quartz is restricted to veins and open space infillings in rocks of the central district. Vesicles of trachyte contain quartz with pyrite and calcite at one location in Baxter Gulch (Fig. 42).

Hematite commonly replaces magnetite with a pattern characteristic of regular martitization (Fig. 43). Pyrite is also replaced by hematite (Fig. 44). Hematite has a banded or colloform texture in veins with calcite, pyrite, gold, and quartz.
Figure 43. Triangular pattern of regular martitization, hematite replacing magnetite. Plane reflected light.

Figure 44. Replacement textures in hematite after pyrite, from a vein in the Old Abe breccia. Plane light.
GEOLeGIC STRUCTURE

Regional Setting

The White Oaks district is on the margin of the Moquino Arch to the east, the Clauses Sag to the west, and the Sierra Blanca Basin to the south (Kelley and others, 1964). The only major structural element in the map area is the White Oaks Fault, an arcuate fracture 32 km in length, a normal fault downthrown to the southeast (Fig. 1 and Fig. 45).

Structure of the White Oaks District

The structure within the White Oaks district is directly related to local intrusive activity. The Permian-Cretaceous sedimentary sequence is upwarped marginal to the Lone Mountain intrusive. The continuation of the sedimentary structures around the south and southeast margins of Lone Mountain is disrupted by the intrusive activity associated with the emplacement of a smaller stock into the north and central portions of the district. The width of the intrusive is 2.1 km. The shape is approximately circular (Fig. 19) and is modified by radiating dike structure. The stock, associated structures, and the enclosing sediments are cut by a series of small plugs and short dikes. Minor fractures with displacements of less than 0.1 m (Lingren and others, 1910)
are mineralized by hydrothermal solutions in the central district.

Folds

Folding in the map area is minor. Sediments throughout the district dip to the south, with steeper dips near the margins of the Lone Mountain intrusive. Minor folding and dip reversals are related to local intrusive activity.

Faults

The White Oaks fault is the only major structural element in the map area. The fault trends north along the eastern margin of the district (Fig. 45). Haines (1968) mapped and described the White Oaks fault as a normal fault dipping 80 degrees to the southeast with a maximum throw of 610 m. In the White Oaks district, neither horizontal nor vertical separation can be measured from exposures in the map area. Because both sides of the fault are within the Mancos Shale Formation, the vertical displacement should be less than the width of the formation, 183 m.

In the northeast quadrant of the map area, a right-lateral separation of 200 m is apparent on a fault displacing Dakota Sandstone (B in Fig. 45). Another small fault in the northwestern quadrant involves a strike-slip component of 25 m,
Figure 45. Trace of the White Oaks fault (A) and a smaller fault in Dakota Sandstone (B). Trenches through a contact-metamorphic magnetite deposit on the southeast slope of Lone Mountain located at C. View to the north.

Figure 46. Approximate trace of a small fault in Triassic and Cretaceous sediments of the northwestern part of the district. Sierra Blanca is in the background of this view to the south.
as measured from the displaced margin of a vertical dike (Fig. 46). The displacement on both faults and the disruption of the sedimentary sequence along the northern margin of the map area are due to the intrusive force of the centrally located syenite porphyry stock.

Slumping and high-angle gravity sliding has occurred in the southern and western parts of the district. Two slump features are present in Mancos Shale on the west bank of Baxter Gulch (Fig. 12) and similar structures are present on the west slope of Baxter Mountain. Landslide debris derived from the Carrizo intrusive form the eastern margin of Baxter Gulch in the southeast portion of the district.
MINERALIZATION

General

Mineralization in the White Oaks district is represented by magnetite, hematite, pyrite, wolframite, gold, and pyrrhotite.

Magnetite is present as fine-grained disseminations in intrusive igneous rocks and as float derived from contact metasomatic replacement deposits marginal to the Lone Mountain intrusive (C in Fig. 45) (Kelley, 1949). Hematite is ubiquitous, staining sediments and some igneous rocks, filling veins, replacing pyrite and magnetite, and crystallizing as specularite in the Chinle-Dakota intrusive breccias and adjacent sediments (Fig. 51). Pyrite is disseminated in some dikes and plugs, is found in cavities in some trachyte porphyry dike rocks, and is associated with breccias of the central district. Pyrrhotite is found in metamorphosed shales in the east-central part of the map area.

Wolframite is associated with quartz in veins within the central mining district. Chemical analysis indicates that huebnerite is the dominant tungstate. Gold is present with the tungsten, but is reported to be concentrated in limonite veins, minor breccia zones, and small vertical
fractures (Griswold, 1999). Small-scale placer gold deposits have been worked in Baxter Gulch, with varying results. Chalcopyrite is present on nearly every large mine dump in the district. The mineral has not been observed in rock exposed in place at the surface.

The ore deposits in the White Oaks district may be classified as epithermal. Open-space infillings are the dominant form of ore deposition. The propylitic alteration and alteration products, such as chlorite, calcite, pyrite, and epidote, are also characteristic of an epithermal deposit.

The gold and tungsten mineralization in this district is hydrothermal in origin. Crystallization in veins or vugs begins with pyrite, followed by calcite, quartz, and hematite. Tungsten mineralization is more closely associated with the quartz stage, and the gold is contemporaneous with some phases of hematite deposition. Not all veins of hematite are gold bearing and only a small percentage of the observable quartz occurrences are associated with either gold or tungsten.

The host rock varies with each mine and within each mine. Gold-tungsten mineralization also appears to be confined to the central district. Gold-bearing veins consistently trend between 5 degrees east or west of north and are very steeply dipping to vertical. Width of the veins varies from
less than a millimeter to more than 45 mm (Lindgren and others, 1910). Generally, the veins are short in the horizontal dimension, less than 100 m, but the vertical dimension is extensive; gold mineralization in the Old Abe is continuous to a depth of 421 m (Lindren and others, 1910).

Economic Deposits

Gold Deposits

The White Oaks district has produced more than 3 million dollars (152,373 ounces at $20 per ounce) from gold production between 1889 and 1951. At today's prices on the world market ($170 per ounce), the mined gold would be valued at 2.6 billion dollars.

The leading producer in the district was the Old Abe (Fig. 47), with 45,745 ounces produced from a steeply dipping vein striking N. 10° W. (Lindgren and others, 1910), mined to a depth of 503 m (Simpson, personal communication, 1974). The main lode was in brecciated shales and monzonite, porous and somewhat silicified and stained with iron (Lindgren and others, 1910). The Fish Pond stope (Fig. 48), 6 m wide and 15 m long and 18 m high, was said to have yielded $80,000 (Lindgren and others, 1910).

The second largest producer was the South Homestake (Fig. 49), where the gold was concentrated in the Captain
Figure 47. Gold ore sample from the Old Abe property. Courtesy of Owen H. Simpson, White Oaks, N. M.

Figure 48. The Old Abe mine workings, dumps are in the foreground and a portion of the Fish Pond stope is visible where indicated (A).
Figure 49. South Homestake workings. South Homestake Shaft (A), the Captain’s Kitchen (B), and the Devil’s Kitchen (C) stopes where indicated.
and Devil's Kitchen stopes, both located just north of the main shaft. The gold was deposited in closely spaced vertical fractures striking north and filled mostly with limonite. The South Homestake produced 30,000 ounces of gold between 1879 and 1903 (Griswold, 1959).

The North Homestake is the third largest producer. The mine location marks the site of the original lode discovery in the district. The mine produced 20,039 ounces of gold from nearly vertical fractures in lamprophyre (Lindgren and others, 1910).

Tungsten Deposits

The tungsten ore mineral in the White Oaks district is huebnerite. A representative chemical analysis is given in Table 1.

Table 1. Tungsten Ore Analysis  
(John Husler, chemist, June 22, 1973)

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>% BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>WO₃</td>
<td>66.6 (76.57% Theor. for MnWO₄)</td>
</tr>
<tr>
<td>FeO</td>
<td>5.2</td>
</tr>
<tr>
<td>MnO</td>
<td>20.6</td>
</tr>
</tbody>
</table>

Huebnerite is not exposed on the surface. Mine dump samples indicate the mineral occurs as short, black blades in a quartz matrix (Fig. 50), and is deposited in small-scale
Figure 50. Blades of huebnerite as viewed in plane reflected light, enclosed in quartz (dark).

Figure 51. Specularite blades as viewed in plane reflected light, A polished section from Chirle Shale in the northern portion of the mapped area.
shear zones. The associated fluorescent mineral is calcite. Gold does occur with tungsten mineralization.

In the years the district was most active (1889-1904), huebnerite was not considered an ore mineral. Complete records of tungsten production are not available; the U. S. Bureau of Mines reports that tungsten production from Lincoln County through 1952 was 119,933 pounds of $\text{WO}_3$ concentrate (with an average grade of 56.18%) (Griswold, 1959).
SUMMARY

1. The sedimentary sequence in the White Oaks district includes Permian sandstone, limestone, and gypsum from the San Andres Formation; Triassic Santa Rosa and Chinle sandstone, siltstone, and shale; and Cretaceous sandstone and shale in the Dakota, Mancos, and Mesaverde formations. The sequence has been upwarped marginally to intrusives.

2. Igneous rocks are post-Cretaceous and occur as dikes, small discordant plutons, sills, or as part of a large stock. The main intrusive is a syenite porphyry stock with brecciated margins modified by radial, sinuous extensions of syenite porphyry into the surrounding sediments.

3. Sediments on the margins of intrusives have been altered to hornfels or quartzite. Most igneous rocks in the district have been sericitized and propylitically altered.

4. Mineralization in the district is represented by magnetite, hematite, pyrite, wolframite, gold, and pyrrhotite. Epithermal ores are found in north-trending hydrothermal veins.

5. A geologic description of the sedimentary rocks, igneous rocks, and associated structures may assist in the preparation of exploration programs and provide a more complete interpretation of the geology in the Lincoln County Porphyry Belt of south central New Mexico.
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Fig. 52. Structure section along A-A' and B-B' from Fig. 1.