BULLETIN 96

# Geology of the Little Hatchet Mountains Hidalgo and Grant Counties New Mexico

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1970

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO

# *Preface*

This report by Dr. Robert A. Zeller, Jr., was essentially a preliminary draft; he had planned to do a more detailed examination of at least several areas in the Little Hatchet Mountains, measure key stratigraphic sections, and describe the geologic structures with greater emphasis on their relation to the interpretation of the stratigraphic sequence.

Unfortunately, Zeller was killed in an airplane crash in late February 1970, thus this report and his geologic map prepared in February 1968 are being published with only minor modifications gained from his field notes. He had hoped to do a more detailed study under the sponsorship of the New Mexico State Bureau of Mines and Mineral Resources.

Zeller's structural interpretations and his establishment of the Cretaceous-Tertiary stratigraphic sequence differ greatly from those of Lasky (1947). The majority of geologists that have worked in this region agree more closely with Zeller's conclusions. Mapping of numerous thrust faults in the Little Hatchet Mountains is in accord with structures in nearby ranges, and the Cretaceous-Tertiary sequence as interpreted by Zeller fits the regional stratigraphic pattern. These are important, fundamental contributions to the geology of southwestern New Mexico, a region with which Bob Zeller was intimately acquainted. We are pleased to be able to publish this significant geologic report as a small part of Dr. Zeller's geologic findings in the Hidalgo County region.

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The stratigraphic sequence in the Little Hatchet Mountains is, in ascending order, the Pennsylvanian-Permian Horquilla Limestone; the Permian Earp Formation; a 1,500-foot-thick unnamed unit of thin-bedded limestone, dolomite, gypsum, and shale of probable Early Cretaceous age, gradational upward into the Hell-to-Finish Formation, which is a Lower Cretaceous sequence, as much as 6,000 feet thick, of redbeds, arkose, limestone-cobble conglomerate, sandy limestone, and some lenses of andesite breccia; the Lower Cretaceous U-Bar Formation, conformable with adjacent formations, about 4,000 feet thick and consisting of fossiliferous thin-bedded limestone, reef limestone, gray to brown shale, and some arkose; the Lower Cretaceous Mojado Formation, as much as 5,000 feet thick, consisting mainly of gray to tan quartz sandstone with shale interbeds and some thick lenses of conglomerate; the Upper Cretaceous or lower Tertiary Ringbone Formation, unconformable on older strata, as much as 7,500 feet thick, consisting of limestone-cobble conglomerate, black shale, gray shale, thin lenses of arkose, much fossil wood, chert conglomerate, and, in the upper beds, basalt and andesite flows and breccias; and the Hidalgo Volcanics, of probable early Tertiary age, unconformable on older rocks, as much as 5,500 feet thick, composed of andesite flows, breccias, lower cobble conglomerates, and upper volcanic sandstone and shale.

Rhyolitic and latitic pyroclastics with interbedded tuffaceous sandstone and clay, of middle and late Tertiary age, are angularly unconformable on older rocks. Intrusive rocks are: Precambrian granite; Laramide stocks, dikes, and sills of diorite, monzonite, and quartz monzonite; a Tertiary granite stock; and dikes of Tertiary felsite, rhyolite, and latite.

Laramide orogeny was marked by differential uplift, thrust-faulting, and intrusive activity; whereas block-faulting characterized the Tertiary structural movements. Limestone-replacement lead-silver-zinc-copper ore near Old Hachita, low-grade copper in altered monzonite stocks, copper-molybdenite-tungsten ore in skarns near large granitic to dioritic stocks, and some gold-quartz veins are favorable for mineral exploration.

# *Introduction*

The chief purpose of this project was the detailed geologic mapping of the Little Hatchet Mountains on a scale of 1:31,680. About five months of field mapping was done between June 1967 and February 1968. Prior mapping had been done and various geologic studies made in parts of the range as a project for the New Mexico State Bureau of Mines and Mineral Resources; this earlier work was incorporated into the present project.

The geologic mapping was done in detail. In critical places the mapping was in considerably greater detail than can be shown on the map. Unresolved problems remain, but the major problems of structure and stratigraphy were solved. More detailed study of some areas would result in refinement of the map but would not change the gross picture of the geology. Only field identifications were made of igneous rocks; these should be supplemented with petrographic identification.

Two areas need further study and mapping. One is the area mapped as diorite 0.25 mile south of Howells Wells; the other is in N% sec. 29, T. 28 S., R. 16 W. In both areas, andesite breccias occur in what is mapped as the Hell-to-Finish Formation. Near Howells Wells, some of the rock mapped as diorite is extrusive andesite breccia, although much of the rock is intrusive diorite. As volcanic rocks are not known elsewhere in the Hell-to-Finish Formation, the volcanics may belong to the Ringbone Formation that could rest unconformably upon the Hell-to-Finish Formation, or there may be an unrecognized thrust fault that carried the volcanic rocks into these areas.

The Little Hatchet Mountains were studied and mapped geologically by Lasky (1947). Comparisons of his map and mine show great differences, and the burden of proof is mine in areas in which we differ. The key to deciphering the structural geology of the area was the discovery of the correct stratigraphic sequence. I have studied the stratigraphy of this range for 15 years, but the correct sequence of formations was worked out only during the current project. The break-through was the discovery of a particular plant fossil no larger than the head of a match; this confirmed a later age for a formation formerly thought to be much older and led to the confirmation of the thrust faults. The stratigraphic problems were solved by working out the structure along with the sequence of formations.

Rocks in the northern half of the range are not metamorphosed, except for small areas near the Old Hachita stock. The sequence of formations was worked out in this area. The southern part of the range, from the Copper Dick mine southward, has a large percentage of intrusive masses; all sedimentary rocks in this part of the range are metamorphosed. The degree of metamorphism is a function of proximity of intrusive rocks and the composition of individual beds. Metamorphism complicates the study of the stratified rocks in this area.

This report gives only brief descriptions of the formations, structures, and mineral showings intended to help in the interpretation of the geologic map. Only through field observation can a thorough understanding of the complicated geology of the Little Hatchet Mountains be gained.

# *Stratified Rocks*

Descriptions of both sedimentary-and volcanic rocks of the Little Hatchet Mountains are included under the heading Stratified Rocks. Sedimentary rock formations are of Paleozoic, Mesozoic, and Tertiary ages. Volcanic rocks, which are mainly pyroclastic deposits but include some flow breccias and flows, are of probable Late Cretaceous and middle to late Tertiary ages. Detailed descriptions of Paleozoic and Lower Cretaceous formations in the Big Hatchet Mountains are given by Zeller (1965).

## PALEOZOIC FORMATIONS

Massive, white, marbleized limestone exposed in the isolated hills on the west side of Granite Pass is identified as the Horquilla Limestone. Fusulinids preserved in black chert nodules interbedded in the marble are *Pseudo-schwagerina* sp., a genus confined to the upper Horquilla Limestone in the region. White, massive marble of similar appearance at the east end of Granite Pass probably is also the Horquilla Limestone. These masses of Horquilla Limestone are in fault contact with Early Cretaceous beds, and the faults exposed at the east and west ends of the pass are probably the same fault. The Tertiary granite that intruded the Granite Pass area obliterated all but short sections of the fault. The sinuous map pattern of the fault suggests a low-angle thrust.

Another metamorphosed unit of probable Paleozoic age is exposed in the hills at the west end of Granite Pass. The rock is thin-bedded, brown-weathered siltstone and dolomite. The contact of these beds with the Horquilla is a probable fault; the eastern contact with the Horquilla is concealed. This brown, silty unit resembles the Earp Formation, but it could be a clastic zone within the Horquilla Formation.

A small exposure of dolomite and thinly laminated limestone in fault contact with Precambrian granite on the pediment at the west end of Granite Pass may be one of the lower Paleozoic formations, the El Paso Limestone or the Montoya Dolomite.

The Bliss Sandstone rests unconformably upon Precambrian granite and quartzite in the small isolated hills in Hatchet Gap at the southern end of the Little Hatchet Mountains. This area is not included on the geologic map.

These outcrops of Paleozoic rocks were mapped as the Playas Peak Formation by Lasky (1947).

## MESOZOIC FORMATIONS

Most of the sedimentary formations in the Little Hatchet Mountains are of Cretaceous age. The lowest Cretaceous unit, the Hell-to-Finish Formation, rests with apparent conformity upon relatively thin-bedded marine rocks on the eastern slopes of the range south of Howells Wells. The top of the Cretaceous section has not been definitely established because of the difficulty of placing the Cretaceous-Tertiary boundary.

From the standpoint of mineral exploration, absolute age determinations of the formations are not critical. Of greater importance are the ages of the formations relative to orogeny and the period of mineralization. The orogeny that strongly deformed Cretaceous and older rocks, commonly called the "Laramide" orogeny in the region, was responsible for the intrusion of stocks of intermediate composition and the introduction of base metals.

All post-Paleozoic stratified rocks that were deformed by the Laramide orogeny in the range are tentatively classified as Cretaceous. These are overlain with angular unconformity by gently dipping, fresh-appearing volcanic rocks of middle or late Tertiary age.

The Cretaceous section is divisible into six formations. Above the lowest unit, which is of uncertain age, the lower three formations form a depositional sequence unbroken by unconformities. These units are the same as those in the Big Hatchet Mountains and are of Early Cretaceous age. In ascending order they are the Hell-to-Finish, U-Bar, and Mojado Formations. The upper two formations are at least as young as Late Cretaceous and may be early Tertiary. The lower of the two is here called the Ringbone Formation, and the upper is the Hidalgo Volcanics; each rests unconformably upon underlying rocks.

## CRETACEOUS ROCKS

### Unnamed Cretaceous? Beds

Identification of the marine formation that underlies the Hell-to-Finish Formation is an unresolved problem. This formation is unfossiliferous and mostly thin bedded; it consists of marine limestone, dolomite, gypsum, and shale. It crops out mainly in sec. 25, T. 28 S., R. 16 W., and was mapped by Lasky (1947) as the lower part of his Broken Jug Limestone. Its maximum exposed thickness is about 1,500 feet. As some of the thin carbonate rock beds are brown weathered and silty, the formation was at first thought to be the Permian Earp Formation. The presence of gypsum beds and dolomite suggested that the formation may be the Permian Epitaph Dolomite. The formation is probably not of Permian age because of the absence of the pronounced unconformity that separates Paleozoic and Cretaceous strata throughout the region. The upper beds of limestone and shale of this enigmatic formation are interbedded with limestone conglomerate beds typical of the overlying Hell-to-Finish Formation. The contact seems to be gradational and is arbitrarily chosen at the base of the lowest of the prominent limestone conglomerate beds; this seems to be the approximate division between marine beds below and terrestrial beds above.

The upward lithologic gradation of this unknown formation into the lithology of the Hell-to-Finish Formation suggests similar ages for the formations. As the Hell-to-Finish Formation is probably Early Cretaceous, the underlying unit is probably Early Cretaceous, or possibly Jurassic, in age. Marine Jurassic formations are unknown in southwestern New Mexico, but the unit could represent a northern remnant of a Mexican marine Jurassic formation.

A complicating factor in the identification of this unknown formation is that its original character and any fossils have been altered by metamorphism.

## Hell-to-Finish Formation

The Hell-to-Finish Formation consists mostly of red shale, gray shale, red siltstone, limestone-cobble conglomerate, arkose, and sandy (arkosic) limestone. Limestone conglomerate and red elastic beds are predominant in the lower part. Arkose and gray shale are more common in the upper part. Near the top, limestone is more common. The contact with the overlying U-Bar Formation is gradational and is chosen at the level above which limestone predominates. This contact is difficult to locate consistently in the Little Hatchets and is therefore mapped with a dashed line.

Diagnostic features of this formation are: the cobbles of the limestone conglomerate consist of Paleozoic limestone and smaller quantitites of Paleozoic dolomite and chert; fusulinids are common in cobbles of Horquilla Limestone; it contains a few pebbles of basic volcanic rock; limestone-conglomerate beds in higher formations contain at least some Cretaceous limestone detritus. Another distinguishing feature of the Hell-to-Finish Formation is that this is the only formation having conspicuous redbeds.

The formation crops out in several areas. A large area of exposure is on the northern slopes of Howells Ridge, where its base has been cut out by an overthrust fault; upward it grades into the U-Bar Formation. It is also exposed in the area of Old Hachita; here the base is concealed by alluvial cover and a fault, but the top is exposed. The largest area of exposure is in the center of the range, where it has been complexly intruded and metamorphosed. In this area the approximate thickness of the Hell-to-Finish Formation is 6,000 feet.

In two areas there seems to be andesite breccia within the Hell-to-Finish Formation. One area is 0.25 mile south of Howells Wells, and the other is south of the fault in sec. 29, T. 28 S., R. 16 W. Unresolved structural problems make it uncertain whether the volcanics are within the Hell-to-Finish Formation or are part of a younger formation that has been thrust into these areas.

The limestone-conglomerate beds in the lower part of the Hell-to-Finish Formation are so conspicuous and, in places, are so thick that the conglomerate could be mapped as a distinct member. The conglomerate appears to be equivalent to the Glance Conglomerate of southeastern Arizona; the remainder of the Hell-to-Finish Formation correlates with the Morita Formation of southeastern Arizona. Lasky (1947) mapped this formation as the upper part of the Broken Jug Limestone and the lower beds of the Howells Ridge Formation, particularly near and south of Broken Jug Pass and near Old Hachita.

## U-Bar Formation

The U-Bar Formation, which is characterized by marine limestone, is conformable with the Hell-to-Finish Formation below and the Mojado Formation above. The informal members of the U-Bar Formation described in the Big Hatchet Mountains area are all recognized in the Little Hatchets, although all are somewhat thinner. From the base upward, the lithology is as follows: interbedded brown shale, arkose, and limestone (brown limestone member); thin beds of conspicuously fossiliferous limestone with abundant oysters and gray shale (oyster limestone member); interbedded thin beds of black, dense limestone and gray shale (limestone-shale member); massive reef limestone (reef limestone member); thin beds of limestone, some with *Orbitolina* (suprareef limestone member).

The entire formation is not well exposed or preserved anywhere in the range. In the southern part of the Little Hatchet Mountains it is metamorphosed; in the northern part it is metamorphosed only in small areas, but it is broken by faults and partly concealed by alluvium. The best unmetamorphosed exposures are near Old Hachita. The upper part of the formation is well exposed on the south side of Howells Ridge, but a thrust fault at the base of the cliffs on the ridge obliterated nearly all of the prereef part of the formation.

In the central part of the range the formation is intruded and metamorphosed by stocks and sills. Here the U-Bar Formation has a thickness of about 4,000 feet.

This formation is easily recognized because it is the only predominantly carbonate-rock Cretaceous unit in the range. The only other marine limestone beds in the Cretaceous section are in the underlying and overlying formations near contacts with the U-Bar Formation. Cretaceous fossils serve to distinguish the U-Bar from Paleozoic carbonate-rock units. This formation correlates with the Lowell and Mural Formations of southeastern Arizona. Lasky (1947) mapped the U-Bar Formation in the upper part of his Howells Ridge Formation throughout most of the Little Hatchet Mountains.

The reef limestone near the top of the U-Bar Formation is the host for replacement ore bodies in the Old Hachita area. This massive limestone forms the base of a number of thrust sheets in the Little Hatchet Mountains.

### Mojado Formation

The Mojado Formation rests conformably upon the U-Bar Formation and is overlain unconformably by the Ringbone Formation. The formation has the same characteristics in the Little Hatchet Mountains as in the Big Hatchet and Animas Mountains. It consists mainly of gray and tan quartz sandstone beds with shale interbeds that are concealed in most areas. The lower few hundred feet have a few thin beds of limestone similar to the upper limestone of the U-Bar Formation. Several thousand feet above the base in the area 0.5 mile north of the Copper Dick mine, greenish shales are predominant over sandstone. Above the shale in the same area are beds of boulder conglomerate, some with boulders up to 35 feet in diameter; all the boulders are of U-Bar Limestone. Above the conglomerate are alternating sandstone and shale beds with a few calcareous marine beds containing late Washita mollusks *Corbula* sp., *Mesalia seriatim-granulata* (Romer), *T. delriensis* Stanton?, *Anchura?* sp., *Avellana tarrantensis* (Cragin)?, *Ostrea* sp., *Gryphaea* sp., *Cardita* sp., and *Homomya* sp.

About 2 miles north of Old Hachita, the upper part of the Mojado Formation has similar characteristics. A thick section of predominant shale is overlain by beds of sandstone and limestone conglomerate composed of U-Bar and lower Mojado detritus. The coarse detrital fraction consists mostly of cobbles and small boulders in contrast to the gigantic boulders in the area to the south. The cobble conglomerates are overlain by sandstone and shale. A few calcareous marine beds have Washita fossils.

North of Granite Pass, several thousand feet of Mojado Formation rests upon the U-Bar Formation. The upper part of the formation is cut off by a granite stock.

The Mojado Formation is overlain with angular unconformity by younger formations. Along the eastern rim of the basin east of Playas Peak, the Ringbone Formation rests with angular unconformity upon an erosionally truncated section ranging from high to basal Mojado. A mile south of the Hornet mine, a thin basal remnant of Mojado is overlain unconformably by the Hidalgo Volcanics. A mile and a half south of Playas Peak, lower Mojado is overlain unconformably by young Tertiary rocks. Elsewhere in the range the upper contact is a fault or it is concealed by alluvium.

The Mojado Formation in the Little Hatchet Mountains has an estimated maximum exposed thickness of 5,000 feet. The Mojado correlates with the Cintura Formation of southeastern Arizona (Stoyanow, 1949), the Sarten Sandstone of Cooks Range (Kottlowski, 1963), and the Johnny Bull Sandstone of the Peloncillo Mountains (Gillerman, 1958). Lasky's (1947) outcrops of the Corbett Sandstone and part of his Broken Jug Limestone east of Ringbone Ranch are Mojado Formation rocks.

## Post-Mojado—Pre-Ringbone Unconformity

After deposition of the Lower Cretaceous formations, the Little Hatchet Mountains area was somewhat deformed and deeply eroded prior to deposition of the Ringbone Formation. The Ringbone Formation rests with angular unconformity upon the Mojado, the U-Bar, and the Hell-to-Finish Formations.

As the age of the highest beds of the Mojado Formation is latest Early Cretaceous, the period of deformation and erosion responsible for the pre-Ringbone unconformity probably occurred in Late Cretaceous time. This deformation may have been an early phase of the Laramide orogeny.

## Ringbone Formation

The Ringbone Formation is exposed in four areas in the northern part of the Little Hatchet Mountains, all separated by overthrust faults. It has not been identified in the central and southern part of the range. The northernmost exposure is near Ringbone Well (called Ringbone Ranch on map); the second is north of the western end of Howells Ridge (secs. 29-32, T. 27 S., R.

16 W.; mapped as Howells Ridge Formation by Lasky, 1947); the third is on the east, south, and west sides of Playas Peak (mapped as Skunk Ranch Conglomerate and Playas Peak Formation by Lasky, 1947); the fourth is at the base of the hills northwest of Livermore Spring (Lasky's Skunk Ranch Conglomerate, 1947). In each area the lithology is different in detail but similar enough to confirm identification of the formation. The Ringbone is entirely terrestrial and includes all of the strata mapped as Skunk Ranch Conglomerate and most of the outcrops of Playas Peak Formation as mapped by Lasky (1947).

Beds and lenses of limestone-cobble conglomerate are found at and near the base of the formation in most places. The cobbles are mostly derived from Paleozoic limestone, but Cretaceous limestone cobbles are usually present, although rare. From the base to about the upper third of the formation black, bituminous shale and gray shale are the predominant rock types. Thin beds of arkose are interbedded with the shale and in places are numerous. Fossil wood is common.

Volcanic flows occur in the upper third of the Ringbone Formation in the area south of Ringbone Well. The flows are basalt and andesite porphyry. A few concentrations of basaltic volcanic breccia may represent small cinder cones. The flows are interbedded with black shale and increase in number upward but do not predominate over the sedimentary rocks.

In the area north of the western end of Howells Ridge, a few local basic volcanic flows are in the lower part of the Ringbone. Flows are also present in the upper half of the formation. A prominent hill composed of basalt breccia is interpreted as a cinder cone formed during Ringbone deposition. Volcanic flows are not present in the Ringbone Formation near Playas Peak. Andesite or basalt flows occur in the upper part of the exposed Ringbone northeast of Livermore Spring.

Conglomerate is common in the upper part of the Ringbone Formation. Southwest and west of Playas Peak, limestone-cobble conglomerate dominates the upper part of the formation and is interbedded with arkose and shale. North of the western part of Howells Ridge, limestone- and chert-pebble conglomerate beds and lenses are found in the upper part of the Ringbone, although the conglomerate is not as common as are arkose and shale.

The upper part of the Ringbone Formation is cut by angular unconformities. South of the Ringbone Well, the Hidalgo Volcanics rest with angular unconformity upon the Ringbone Formation. West of Playas Peak and northwest of Livermore Spring, the young Tertiary rocks rest with angular unconformity upon the Ringbone. The episodes of erosion associated with the unconformities cut to various depths into the Ringbone so that different thicknesses are preserved in the different areas. The maximum exposed thickness in the vicinity of Playas Peak is 7,500 feet.

The Ringbone Formation is of Late Cretaceous or early Tertiary age. A plant fossil collected from the formation was identified by Charles B. Read as a species of *Sabal,* a fossil palm restricted to rocks of Late Cretaceous and Paleocene or early Eocene in the southwestern United States.

# CENOZOIC ROCKS

## TERTIARY ROCKS

### Post-Ringbone—Pre-Hidalgo Unconformity

The Hidalgo Volcanics rest with angular unconformity upon older formations along the contact extending from south of Ringbone Well to about 3 miles south of Old Hachita. Southeastward along this contact, the underlying rocks are successively older, ranging from high Ringbone to basal Ringbone, to Mojado, and to the U-Bar Formation.

After deposition of the Ringbone Formation, the area was deformed and eroded, with deposition of the Hidalgo volcanic rocks upon the erosion surface. This episode of deformation and volcanic eruptions increased in tempo from late Ringbone to Hidalgo time, and probably represents an early stage of the Laramide orogeny, which did not reach its climax until after deposition of the Hidalgo Volcanics.

### Hidalgo Volcanics

The Hidalgo Volcanics rest unconformably upon older formations, and their upper part is truncated by overthrusts in all areas of exposure. Thus the character of any overlying rocks and the original thickness of the Hidalgo are not known. The maximum exposed thickness is about 5,500 feet in the volcanic area south of Ringbone Well.

Lenses and beds of cobble conglomerate are present in places at the base of the Hidalgo. Most of the cobbles are limestone and sandstone. A few are basalt porphyry with large plagioclase laths; these were derived from distinctive flows in the underlying Ringbone Formation.

The formation consists mostly of andesite flows. Most of the rock is flow breccia and has a distinct breccia structure. Some units are finely crystalline without breccia structure, whereas other units are coarsely porphyritic. Inconspicuous bedding planes or flow planes are present. All of the rock in the unit is altered, and the general color of the outcrop is dark purplish gray.

In the valley in N% sec. 34, T. 27 S., R. 16 W., sedimentary beds are interbedded in the upper part of the exposed section of the Hidalgo Volcanics. These are mostly sandstone and shale derived from erosion of underlying volcanic rocks.

The age of the Hidalgo is probably early Tertiary. Fossil wood collected from the sedimentary beds in the upper part of the formation in NW'% sec. 2, T. 28 S., R. 16 W., was examined by Charles B. Read. The wood is dicotyledonous, similar to that of the modern willow *Salix.* It is probably Tertiary, with only a slight possibility that it is Late Cretaceous.

### Post-Hidalgo—Pre-Late Tertiary Unconformity

Young volcanic rocks of middle to late Tertiary age rest with angular unconformity upon older rocks. The Tertiary volcanic sequence has a gentle dip, usually less than 10 degrees. Underlying rocks, on the other hand, are strongly deformed.

During the hiatus represented by this unconformity, the most intense period of deformation since Precambrian time subjected the region to strong folding, high-angle and thrust faulting, intrusion of monzonitic stocks, metamorphism, and mineralization. This was the Laramide orogeny. Deep erosion followed the orogeny, and the young Tertiary sequence was deposited upon the erosion surface.

## Late Tertiary Volcanics

The sequence of late Tertiary volcanic rocks is mapped as a single unit having the symbol Tv. The rocks consist chiefly of rhyolite and latite pyroclastics. A thin basal section consists of tuffaceous sandstone and clay beds, and similar thin sedimentary units are found higher in the sequence. These young rocks are fresh in contrast to the altered volcanic rocks of preLaramide formations. They are exposed in the northern and northwestern parts of the mapped area, and rest with angular unconformity upon older rocks. Although no direct evidence of the age of these rocks is available, the young volcanic sequence of this region is generally considered to be Oligocene or younger.

# *Intrusive Rocks*

## PRECAMBRIAN GRANITE AND APLITE

The southern part of the Little Hatchet Mountains between Granite Pass and Hatchet Gap consists mostly of coarsely porphyritic Precambrian granite, with a coarsely crystalline groundmass. A system of northeastward-striking aplite dikes cuts the granite. The only mineralization known in the Precambrian intrusive rocks is a small copper prospect close to the northern boundary of the granite.

## LARAMIDE INTRUSIVE ROCKS

Many stocks, dikes, and sills of various compositions were intruded into Cretaceous rocks. Some of the stocks were cut by Laramide thrust faults, and diorite sills were intruded along some of the thrusts. The major mineralization of the area was associated with these igneous intrusions. This intrusive activity, the major faulting, and the mineralization all occurred during the Laramide orogeny. The Laramide intrusive rocks are divided into the following groups: Sylvanite intrusive complex, Old Hachita stock, and dikes and sills.

### SYLVANITE INTRUSIVE COMPLEX

The greatest intrusive activity occurred in the south-central part of the Little Hatchet Mountains from Stone Cabin Gulch to the Copper Dick mine. A large diorite stock lies south of the old townsite of Sylvanite. It joins a large monzonite stock that extends from Sylvanite northward and northwestward for several miles. Several smaller outcrops of quartz monzonite lie within and near the monzonite. East of Broken Jug Pass, there are many sills and dikes of monzonite and a thick sill of diorite. Stocks and large sills of diorite form much of the eastern and northern slopes of Hachita Peak. All of these intrusive bodies are closely associated.

The contact between the large igneous masses is gradational in places, such as at Sylvanite, where the diorite and monzonite masses join. Farther northward the contact between monzonite and quartz monzonite is also indistinct. Within the monzonite stock, composition and texture differ from place to place. Diorite, monzonite, and quartz monzonite were mapped separately in a few areas, but many outcrops of indistinct composition were included with the monzonite. In some places biotite is the dominant ferromagnesian mineral, but elsewhere biotite is lacking and pyroxenes are dominant. The plutonic rock in the Sylvanite area is a complex stock with many different rock types. Detailed study is needed to work out the distribution, relationships, and significance of compositional and textural variations. As all mineralization in the central part of the range is associated with these intrusive rocks, detailed study of the rocks may aid in understanding the mineralization.

Small quartz monzonite stocks near Livermore Spring and in Buckhorn

Canyon (NW% sec. 27, T. 28 S., R. 16 W.) were intruded slightly later than was the monzonite. The concentration of mineralization around the edges of these stocks suggests that mineralization was more closely associated with the quartz monzonite than with the slightly older monzonite.

The distinction between monzonite and diorite during the geologic mapping was made mainly on the basis of color; the diorite is very dark gray, due mainly to a dark aphanitic groundmass, and the monzonite is lighter. Petrographic examination may show that the two rocks are similar in composition. Some field relationships suggest that the two rocks may have originated from a common magma and that the darker, more aphanitic rock is a more shallow, or "chilled," equivalent of the more coarsely crystalline monzonite. The slightly younger quartz monzonite may have originated from the same magma at a later stage after partial differentiation. Detailed field study, as well as petrographic study, is needed to confirm this idea.

## OLD HACHITA STOCK

A monzonite stock crops out over an area of nearly 2 square miles west of Old Hachita. Monzonite at the American mine and Old Hachita is probably part of the larger stock, although the mineral composition is slightly different. As in the Sylvanite intrusive complex, the stock exhibits variations in texture and composition. A wide dike of diorite crosses the stock in an east-west direction. The diorite intrudes the stock, but some monzonite dikes seem to be younger.

Mineralization in the Old Hachita region is associated with the monzonite stock and with dikes and sills. The main body of the stock is iron-stained and largely altered to clay minerals. Andesite flows, into which the stock was intruded, are similarly altered near the contact. Zones of altered rock extend from the stock into the andesite. The original character of the rock of these zones, as in the monzonite, has been obliterated. The zones have been mapped as dikes projecting from the monzonite, although it seems more probable that they are simply highly altered zones of andesite.

Although monzonite is present at the American mine, where limestone has been converted to skarn, the ore deposits do not have an obvious or direct relationship to the monzonite. However, an association of the ore with deeper parts of the stock seems possible.

## DIKES AND SILLS

Dikes and sills are common throughout the Little Hatchet Mountains. In the areas near plutonic rock, dikes of monzonite, quartz monzonite, and diorite, closely associated in age and origin with the plutonic masses, are numerous. Dikes and sills at greater distances from intrusive centers are of the same general age.

Diorite dikes north of Old Hachita strike northeastward. North of the western part of the Old Hachita stock, the diorite dikes strike northward. Diorite sills occur in shale beds, such as those in the Hell-to-Finish Formation on the north slope of Howells Ridge. Diorite was intruded along the fault plane of the thrust on Howells Ridge. Latite was intruded locally along the thrust fault north of Livermore Spring.

In the south-central part of the range, dikes of felsite and rhyolite strike westward and extend for miles. They are obviously younger than the other nearby intrusive rocks. Although they have been mapped as Tertiary-Cretaceous in age, as have the monzonite and diorite, they could be younger. The east-west strike of young dikes in the Granite Pass granite suggests the possibility of a similar age for the east-west dikes a few miles to the north.

## TERTIARY INTRUSIVE ROCKS

The granite stock in Granite Pass appears to be younger than the Laramide intrusive rocks. The rock is much fresher in appearance, and there is little associated mineralization. According to a lead-alpha age determination, the rock is 43 to 48 million years old. Somewhat younger dikes of felsite, rhyolite, and latite cut through the granite and bordering rocks. Many of the dikes have an east-west strike. On the geologic map, the Granite Pass granite and the younger dikes are shown as Tertiary in contrast to the Tertiary-Cretaceous (Laramide) age of the older intrusive rocks. The only mineralization known to be associated with the Granite Pass stock is scheelite in garnetized limestone on the southern border of the stock.

Dating of the granite was based on lead-alpha determinations of zircons by the U. S. Geological Survey (Report IWM-902, 4 March 1957) by the courtesy of Carle H. Dane. The relatively fresh, light-gray, porphyritic biotite granite sample (seriate porphyritic granite of Lasky, 1947) was collected in SE1/4 NE1/4 sec. 22, T. 29 S., R. 16 W. The zircons were fresh, doubly terminated crystals, pale orange in color.

# *Structural Geology*

The geologic structure of the Little Hatchet Mountains is more complex than previously recognized. Major structural deformation took place during the Laramide orogeny, when folding, thrusting, and igneous intrusion influenced all older rocks. After the Laramide orogeny, rocks of the area were influenced by gentle folding, igneous intrusion, and high-angle faulting. The structural geology of the Little Hatchet Mountains is described under the following headings: Pre-Laramide Structures, Laramide Structures, and Post-Laramide Structures.

## PRE-LARAMIDE STRUCTURES

The only direct evidence of early structural events in the Little Hatchet Mountains is Precambrian granite, which indicates intrusive activity.

Weak evidence suggests that east-west and northeast trends of some Cretaceous and Tertiary structures may be aligned along Precambrian trends. The northeastward-trending Winkler anticline in the Animas Mountains (Zeller and Alper, 1965) was developed during a number of active periods separated by quiescent times. By analogy with southeastern Arizona, where Precambrian rocks show northeastward-striking structural trends, such trends in the younger rocks of the Little Hatchet Mountains may have been formed by later movements along Precambrian zones of weakness. East-west and northeast structural trends in the Little Hatchet Mountains are shown by many dikes and by the direction of elongation of the Granite Pass stock.

## LARAMIDE STRUCTURES

### DEVELOPMENT OF THE LARAMIDE OROGENY

The first pulse of the Laramide orogeny was in late Washita (late Early Cretaceous) time with the beginning of folding and elevation of local areas above sea level. This early activity is recorded northeast of Livermore Spring and south of Vista, where the upper part of the Mojado Formation contains beds of coarse conglomerate. Cobbles of the lowest conglomerate beds are sandstones from the lower part of the Mojado; higher beds have cobbles of U-Bar limestone. The order of cobbles, U-Bar above Mojado, indicates progressively deeper erosion of the source area, which must have been a nearby anticline or other rising structural high.

The next evidence of deformation is the large relief shown on the pre-Ringbone erosion surface, particularly east of Playas Peak and north of the western end of Howells Ridge. The erosion surface was cut into rocks ranging from high Mojado to Hell-to-Finish, a stratigraphic relief of more than 10,000 feet.

The basal Ringbone Formation includes beds and lenses of limestone-cobble conglomerate that contain some U-Bar limestone detritus, but Paleozoic limestone cobbles are predominant, indicating that uplift of nearby areas exposed Paleozoic rocks to erosion.

As the tempo of the orogeny increased, volcanic flows were extruded in late Ringbone and Hidalgo time. Stocks, dikes, and sills were intruded somewhat later. Although the intrusive rocks cut the volcanic flows, they are probably contemporaneous; possibly the volcanic rocks are a slightly earlier extrusive equivalent of the intrusive, and all may have had a common source.

The economically important mineralization of the area was associated with the intrusive activity. Sedimentary rocks in the central and southern part of the range were metamorphosed by the intrusives. Small areas of limestone and other rocks in the northern part of the range were silicified.

Thrust faulting closely followed the instrusion of stocks and was followed in turn by the intrusion of sills along some thrust planes. Thrusting and the associated intrusions are the last recognized events of the Laramide orogeny in the Little Hatchet Mountains.

## THRUST FAULTS

The shape and arrangement of thrust faults are shown on the geologic map and cross sections. The thrust sheets are saucer-shaped, with one resting upon another and lower thrust sheets being truncated by higher ones. Four major thrust faults were mapped. The lowest lies north of Old Hachita; the next is in the low area south of the American and Hornet mines; the next is at the base of the cliffs following the crest of Howells Ridge; the highest thrust is near Livermore Spring.

The upper two thrusts are at the base of the massive limestone reef of the U-Bar Formation. Angularity of lower beds with the reef was previously attributed to the "unconformity" that in many places occurs at the bases of such reefs. The thrust faults closely follow the same stratigraphic unit for nearly **10** miles, attesting to the lithologic control of the thrust sheets. Correct deciphering of the stratigraphic sequence has proved that these are thrust faults and not unconformities. In some of the Little Hatchet thrusts, older beds are thrust over younger beds, but in other places younger beds are thrust over older beds, with a stratigraphic interval missing. Further confirmation of the thrust faults is that beds in the hanging wall are cut out by the faults. Less conclusive but supporting evidences are the diorite and latite sills along the thrust planes, fracturing and contortion of the rocks above the fault surfaces, and angularity between the thrusts and underlying beds.

The thrusts in many places followed the base of the limestone reef because the limestone formed a thick, massive, homogeneous plate resting upon shale and other relatively incompetent strata. The reef limestone is the thickest and most competent unit in the entire Mesozoic stratigraphic section, and, when the region was subjected to compressional stresses, the bedding-plane thrusts followed this interface between a massive limestone plate and low-friction shale. In places where the limestone reef is not well developed and is thin, thrust faults **did** not occur at this horizon.

In the southern part of the Little Hatchet Mountains, the U-Bar reef limestone is thin and locally missing, and the area was intruded and metamorphosed prior to the period of thrusting. Thrust faults are unknown in this area; metamorphism and silicification hardened the shales and other rocks so that this region probably acted as a solid block during thrusting.

The rocks of the hanging wall or upper plate of the thrusts in the center of the range are folded into synclines. The thrust faults follow the base of the limestone reef throughout most of their exposure, and they probably follow the same bedding plane at depth. Thus, the fault planes have the synclinal shapes of the overlying beds; the axes of the synclines probably closely correspond in vertical angle and direction to the angle and direction of movement of the thrusts. Most likely the synclinal folding of the thrust plates occurred during thrusting and was not due to later folding.

The configuration of the fault surfaces and incomplete evidence from drag folds indicate that thrusting was from the west or west-southwest. As movement on the faults was of the order of miles, the faults can be classed as overthrusts.

A similar system of saucer-shaped thrust faults lies 12 miles due west in the northern end of the Animas Mountains (Zeller, 1958). There, Paleozoic rocks have been thrust over Cretaceous rocks. The regional significance of the east-west trend of faulting in the two mountain ranges has not been determined.

The erosion surface at the base of the Ringbone Formation indicates the presence of a positive area to the west of the Little Hatchet Mountains area shortly before thrusting. In the northern part of the range, the erosion surface cuts into high Mojado beds. Farther to the southwest toward Playas Peak, the erosion surface cuts generally deeper into the stratigraphic section, although thrust faults between the outcrop areas break the continuity. East of Playas Peak, the surface cuts progressively lower in the section from high Mojado to U-Bar. North of Playas Peak the surface cuts even deeper, into lower Hell-to-Finish beds. The deeper the erosion surface cut, the higher the area must have been elevated to permit the deeper erosion. As the deepest erosion is near Playas Peak, and as these rocks were thrust from the west, a positive area is suggested to the west.

Further support for the presence of this western positive area is the large amount of Paleozoic limestone cobbles in conglomerates high in the Ringbone Formation in the Playas Peak and western Howells Ridge area. The source area of the cobbles was sufficiently elevated during Ringbone time to allow erosion to expose Paleozoic rocks.

Two large faults, apparently thrusts, were originally present in the Granite Pass area. Paleozoic limestone was thrust over Cretaceous rocks, and 1 mile to the south Precambrian granite was thrust over Paleozoic limestone. The young Tertiary stock intruded this area and obliterated all but small remnants of these faults. Thrusting may have been from the southwest, although too little of the faults is preserved to confirm the direction of movement.

### FOLDS

In addition to the synclines of the thrust plates, several other large folds were formed during the Laramide orogeny. One is the overturned syncline at the north end of the range. Limbs of other folds in the northern part of the range are cut by thrust faults. Stratified rocks in the southern part of the range all dip southwestward. Laramide folding started before deposition of the Ringbone Formation and continued at least to the time of thrusting.

### HIGH-ANGLE FAULTS

Parts of the thrust-fault planes have steep dips. In places the relative age relationships of rocks on either side of the faults and the steep dips would suggest that they are normal faults, if observed only in the restricted area. An example is the thrust just north of the Copper Dick mine. It has a fairly steep northward dip; the younger Mojado beds on the north side appear to have been down-dropped with respect to the older Hell-to-Finish beds on the south side. This was mapped by Lasky (1947) as a large normal fault, the Copper Dick fault. However, by tracing the fault, its thrust origin was discovered.

A high-angle fault is truncated a short distance east of the Copper Dick mine by the thrust. As plotted on the cross sections, this high-angle fault is probably the southern segment of the thrust that lies north of Howells Ridge.

The ore bodies in the Hornet, American, and King mines are localized along high-angle, northeastward-striking faults that show small movements of tens of feet. Such small-scale high-angle faults are common and were not mapped unless displacements were large enough to show offsets of geologic contacts on the map.

## POST-LARAMIDE STRUCTURES

A large, northwestward-striking normal fault divides the Cretaceous rocks of the Little Hatchet Mountains from the young volcanic rocks of the Coyote Hills in the pass at the northern end of the Little Hatchets. Such northwestward-striking, high-angle faults occur in many of the volcanic ranges of the area. Tilting of fault blocks took place during this faulting.

The latest faulting in and near the Little Hatchet Mountains was the uplift of the Little Hatchet range along bordering Basin-and-Range normal faults. Although these late faults are concealed along the flanks of the Little Hatchets by alluvium, physiographic evidence indicates their approximate locations and strikes. The faults strike northward and lie close to the range. On the west flank of the range, the straight border of the mountain front suggests that the bounding fault strikes northward and lies only a short distance west of the county line along the northern half of the range, and that the fault has a south-southeast strike along the southern part of the range. The east front of the Little Hatchet Mountains is a straight north-south line; a fault-line scarp in the alluvium 1 mile east of the Hornet mine shows the probable location of this northward-striking fault. The Basin-and-Range faults are younger than the system of northwestward-striking faults that separate rocks of the Little Hatchet Mountains from those of the Coyote Hills.

# *Mineral Potential*

## MINERALIZATION

Basic information on the mineral deposits of the Little Hatchet range has been given by Lasky (1947), although his outlook for discovery of major ore deposits was more pessimistic than justified. In 1955, Lasky orally expressed the belief that there may be large deposits of low-grade copper, as well as commercial deposits of other metals, in the Little Hatchet Mountains. This opinion is not expressed in his report.

My geologic mapping of the Little Hatchet Mountains did not include a detailed study of mineral deposits. The brief summary of mineral areas given is based on observations during the mapping and on prior studies.

The area of largest past production is Old Hachita, where the American, Hornet, and King mines each have produced half a million dollars worth of lead and silver, and small amounts of zinc and copper. The ore is in limestone replacement bodies along high-angle faults. There are excellent unexplored targets. The past production from the mines makes it unlikely that large tonnages of ore would be found, although geologic conditions do not rule out the possibility.

One of the best prospects for low-grade copper is the altered monzonite stock just west of Old Hachita. The outcrop is iron-stained due to the abundance of disseminated pyrite in the unweathered rock. Much of the rock has been altered to clay minerals. Turquoise occurs in altered rocks around the borders of the stock. Seven holes drilled in this area by Miami Copper Company failed to discover an ore body, but interest continues in the area.

A similarly altered and iron-stained monzonite stock crops out on the north slope of Howells Ridge near "Smugglers Pass," through which the power line passes. Turquoise has been mined from this stock. This stock and the one west of Old Hachita each have hematite-bearing siliceous zones in the rocks immediately overlying the monzonite.

The Copper Dick mine is in skarn zones containing chalcopyrite and molybdenite. Past production has been mainly from underground workings; an attempt in 1967 to ship ore from an open cut was unsuccessful. Copper-bearing skarn crops out both east and west of the Copper Dick mine. The ore-bearing garnetized limestone beds are in the Hell-to-Finish Formation; their northern dip carries them under a thrust fault. Detailed geologic study of this area is needed to determine the possibility for large tonnages of ore. Of economic interest are the thickness and extent of skarn zones, the possible presence of thicker skarn zones underground or under the thrust fault, the dip of the beds with respect to the dip of the thrust fault, the rocks to be expected under the thrust surface, and whether another thrust lies concealed under the outcropping thrust sheet.

The Little Hatchet mines near Livermore Spring were developed by Mr. and Mrs. Bader to explore copper veins in the roof of a quartz monzonite stock. Quartz veinlets are rare in the stock, but those present contain copper sulfides. The southern boundary of the stock in places is in contact with limestone that has been converted to skarn. The Wyoming prospect is on a chalcopyrite-bearing skarn zone.

The rocks in the area extending from Livermore Spring westward to the Playas Valley, and southwestward to Cottonwood Spring and the Sim Smith ranch, are mineralized. Most of the outcrops are monzonite and diorite of the Sylvanite intrusive complex. Outcropping zones of massive limonite have been explored with shafts sunk below the water table to where the veins consist largely of massive pyrite and quartz. Iron staining and alteration of rocks to clay minerals, especially in topographically low areas near Cottonwood Spring, the Sim Smith ranch, and Sylvanite, have been of sufficient interest to stimulate mild exploration activity in the past. A more detailed geologic examination of this area is warranted.

Gold has been produced in the mountainous area extending from the Buckhorn mine (C sec. 27, T. 28 S., R. 16 W.) southward to the Gold Hill and Pearl mines at the head of Stone Cabin Gulch. Free gold occurs mostly in narrow quartz veins in association with tetradymite. It seems unlikely that large tonnages of gold or other ore could be developed in this area. The country rock in the low area at Sylvanite townsite and in the floor of the valley 0.25 mile to the south is iron-stained and altered. Exploration may be worthwhile in these low areas.

Skarn occurs on the southwest and northeast sides of the Granite Pass stock, where granite is in contact with massive limestone. Scheelite has been found in these skarn zones.

The areas mentioned are the most promising for mineral exploration. Small, less impressive shows of mineralization are present in other parts of the range. Detailed geologic study of the more promising mineral areas is recommended.

## RECENT MINERAL ACTIVITY

From 1950 to the present, there has been sporadic exploration and small-scale mining in the Little Hatchet Mountains. For convenience of description, the Little Hatchets is here divided into the Old Hachita region to the north and the Sylvanite-Bader region to the south; Howells Ridge is the dividing line.

The chief activity in the Old Hachita region has been at the Hornet and American mines. In the early 1950's, Eugene Bruell operated the Hornet mine until it became unprofitable. About 1955, the Hornet mine was reopened by a group from Odessa, Texas, and was operated for six months or more. Two bodies of high-grade ore were mined profitably, but the operation was discontinued when the visible ore was exhausted; no exploration was done. A few years later, Gibraltar Minerals Company, a subsidiary of Harvest Queen Mill and Elevator Company of Plainview, Texas, leased the Hornet mine, drilled ahead to locate the next ore body, and developed the mine to greater depths in extracting ore. The operation was discontinued in 1958 when the cost of sinking to the next ore body, which had been located by drilling, was judged to be greater than the expected returns from the ore. The Hornet mine has not operated since.

The American mine was dewatered, mapped, and sampled in 1956 by Haile Mines, Inc. Although 5,000 tons of ore carrying 7.3 ounces of silver per ton and 10.9 percent lead were blocked out, in addition to a quantity of lower grade ore, Haile Mines dropped the lease.

In 1958, Gibraltar Minerals Company acquired the lease on the American mine and began operation shortly after closing the Hornet mine. During 1959 and 1960, Gibraltar extracted the ore that had been blocked out by Haile Mines, a total of about 12,000 tons, which was processed at the Hornet mill. The operation was profitable as long as ore was mined, but, after the previously known ore was exhausted, costs exceeded receipts when the shaft was sunk 100 feet and a new level was developed. A small-scale exploration program failed to discover new ore. According to the geologic maps and cross section that I prepared, the new level of the mine was driven almost to the expected ore zone but did not extend into it. Despite my recommendations, no drilling was done ahead to search for ore. Gibraltar drilled shallow surface holes on various parts of the property, but in unlikely places without reference to the geology of the district; thus no ore was discovered. Gibraltar closed the mine in early 1961 after producing $112,000 worth of lead and silver.

In late 1964, Rosario Exploration Company acquired a lease on the American mine and adjoining properties and staked 50 claims. Rosario was searching for a much larger ore deposit than that of the American mine. They began with a surface magnetometer survey that gave no guides to ore, as much of the area surveyed was blanketed with magnetite-bearing andesite. Next, they ran several induced-polarization profiles across the American mine area. This was followed by the drilling of three vertical holes on induced-polarization anomalies; the deepest hole was about 500 feet. The holes appear to have been located with little regard for the geology. The results were negative, and Rosario terminated the lease late in 1965.

The most significant exploration activity in the Old Hachita region was done by Miami Copper Company in late 1959. Miami drilled seven vertical holes, reportedly about 600 feet deep, in the area of altered monzonite west of Old Hachita. The drill cuttings showed pyrite. As Miami abandoned the claims after drilling, the results must have been disappointing. Woodrow ("Woody") W. Simmons, Miami Copper Company, Miami, Arizona, was in charge of the exploration program.

In the Sylvanite-Bader region south of Howells Ridge, most of the activity since 1950 has been on the Bader properties. In 1954, a group from Tucson, Arizona, called the Tuco Mining Company, leased the Bader properties and the Copper Dick mine. They did little to explore or develop the minerals of the area. They made a number of bulldozer cuts and sank a 30-foot shaft on the Bader properties. They developed the open cut at the Copper Dick mine and from it shipped a small quantity of ore; reportedly this was not profitable. Harrison Schmitt, consulting geologist from Silver City, made a brief geological study of the area and recommended drilling several holes to explore the copper veins on the Bader properties, but the drilling was not done. The company lost its financial backing and gave up its program in the Little Hatchets a few months after starting.

Bear Creek Mining Company conducted a brief exploration program, under the direction of Ray Gilbert, in the Sylvanite-Bader region during the first half of 1961. They leased the Bader properties and staked a large number of claims to the south and southwest. Their activities included reconnaissance geologic mapping, a magnetometer traverse across the Copper Dick fault, and a geochemical survey. Shortly after staking the new claims, Bear Creek abandoned the exploration program in the Little Hatchet Mountains.

In 1962, the Bader properties were leased by Western Beryllium Corporation of Colorado. That company staked 50 or more claims southwest of the Bader ground in the area of the Cottonwood and the Sim Smith ranch, but dropped the lease and the claims without doing serious exploration.

The Bader properties were leased to C. C. Huston and Associates, mining and geological consultants, Toronto, Canada, in 1965. This group became interested in the Bader area as a result of an airborne magnetometer survey. They made a geological study of the claims, conducted an induced-polarization survey, and drilled three diamond-drill holes. The lease was terminated by the company after the drilling. In 1966, the Bader properties were leased to David A. Ross, West Vancouver, Canada. After drilling several shallow holes, Ross cancelled the lease.

During the summer of 1965, U. S. Lime and Mining Company of Silver City, New Mexico, staked a claim about 1 mile north of the Copper Dick mine and drilled a vertical hole. According to unreliable information, the hole was drilled deeper than 1,000 feet, but judging from the small quantity of drill cuttings at the site it seems doubtful that the hole was that deep. The cuttings are of sandstone and shale with no sign of mineralization.

Southern Union Production Company, Dallas, Texas, carried on an exploration program in the region during the winter and early summer of 1967 under the direction of Ray C. Boardman. Claims were staked near the Cottonwood and three test holes were drilled with negative results. Claims also were staked in the area from the J. M. Smith ranch to north of Howells Ridge. A test hole was drilled in NW% sec. 4, T. 28 S., R. 16 W., to a depth of about 1,800 feet. This location was chosen on the basis of an airborne magnetometer survey. Results of the drilling were discouraging and the exploration program and claims in the Little Hatchets were abandoned.

Besides the exploration and mining activities described above, geologists from a number of companies have made brief examinations of parts of the Little Hatchet Mountains that did not result in further exploration.

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Base prepared from parts of Hachita and Playas quadrangles, U. S. Geological Survey, 1918

## EXPLANATION

**QUATERNARY**

Qal — Alluvium
*Includes pediment deposits*

*ANGULAR UNCONFORMITY*

**TERTIARY**

Tf — Felsite; Td — Diorite; Tr — Rhyolite
*Dikes intruded into young Tertiary granite*

Tg — Granite
*Stock and dikes of granite porphyry; lead-alpha age 45 million years*

Tv — Volcanic rocks, undifferentiated
*Latite, quartz latite, and rhyolite flows and pyroclastic deposits*

*ANGULAR UNCONFORMITY*

**UPPER CRETACEOUS OR LOWER TERTIARY**

TKs — Silica rock
*Silicified limestone, monzonite, and other rocks; in irregular masses and veins*

TKg — Granite

TKf — Felsite; TKl — Latite; TKr — Rhyolite
*Dikes and sills intruded into Cretaceous and Tertiary-Cretaceous rocks*

TKqm — Quartz monzonite
*Stocks and sills*

TKm — Monzonite; TKd — Diorite
*Stocks, dikes, and sills*

Khv — Hidalgo Volcanics*
*Altered andesite and andesite breccia; a few sedimentary beds composed of andesite detritus*

*UNCONFORMITY*

**UPPER CRETACEOUS**

Kr — Ringbone Formation
*Black and gray shale, arkose, limestone conglomerate and flows of andesite and basalt; considerable variation in lithology in different areas of exposure*

*ANGULAR UNCONFORMITY*

**LOWER CRETACEOUS**

Km — Mojado Formation
*Thin-bedded quartz sandstone and shale*

Ku — U-Bar Formation
*Predominantly marine limestone with interbedded shale; massive limestone reef near the top*

Kh — Hell-to-Finish Formation
*Thin-bedded red and gray shale and arkose; limestone-cobble conglomerate beds present throughout and abundant in lower part; lower and upper contacts gradational and difficult to map*

**CRETACEOUS?**

K? — Cretaceous? beds
*Thin-bedded limestone, dolomite, and shale; conformable with overlying formation*

*UNCONFORMITY*

**PENNSYLVANIAN PERMIAN**

Pe? — Earp Formation?
*Thin-bedded dolomitic siltstone and silty dolomite*

PPh — Horquilla Limestone
*Massive limestone*

*UNCONFORMITY*

**PRECAMBRIAN**

pCa — Aplite
*Dikes cutting Precambrian granite*

pCg — Granite
*Coarsely crystalline porphyritic granite*

Contact
*Dashed where approximately located*

Fault, showing dip
*Dashed where approximately located. Question mark indicates doubtful or probable fault. U, upthrown side; D, downthrown side.*

Thrust fault
*T on upper plate*

Concealed fault

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

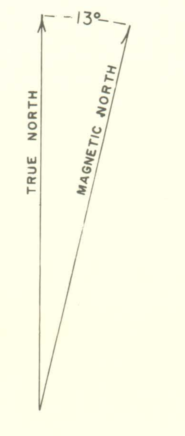
Horizontal beds

Drill hole

Mine

Prospect

* Recent paleontologic and radioactive dating suggest the Hidalgo volcanic rocks are of early Tertiary age

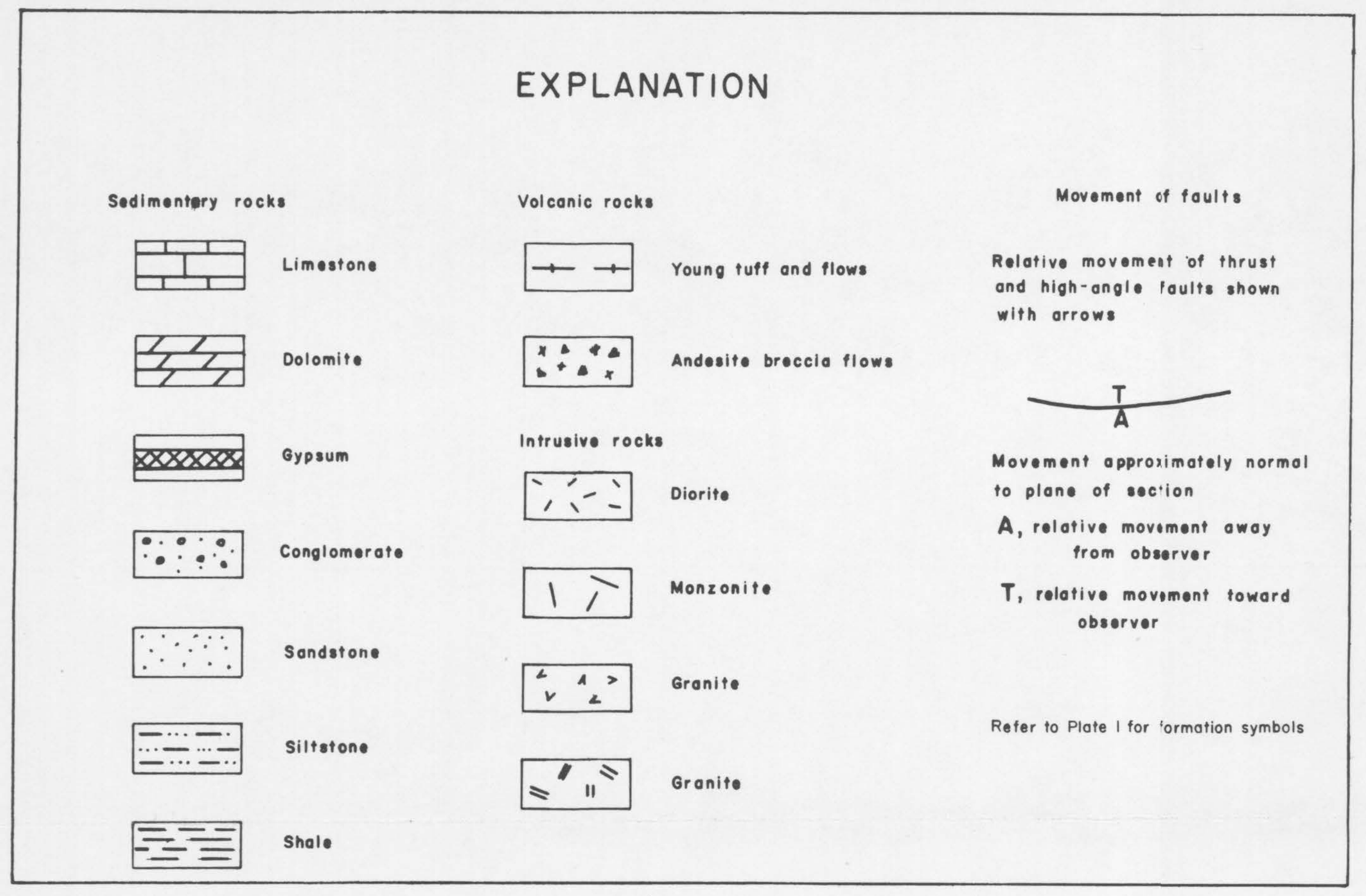


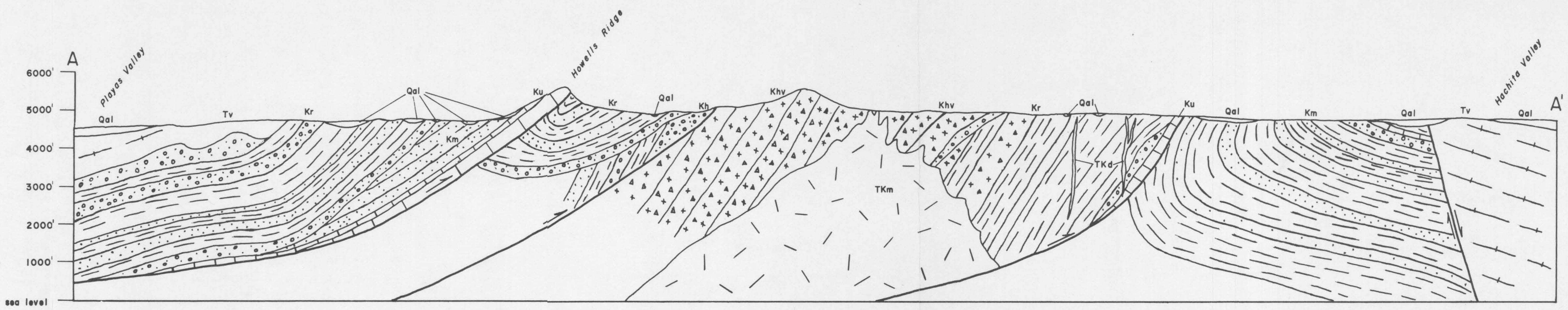

# GEOLOGIC MAP OF THE LITTLE HATCHET MOUNTAINS, NEW MEXICO

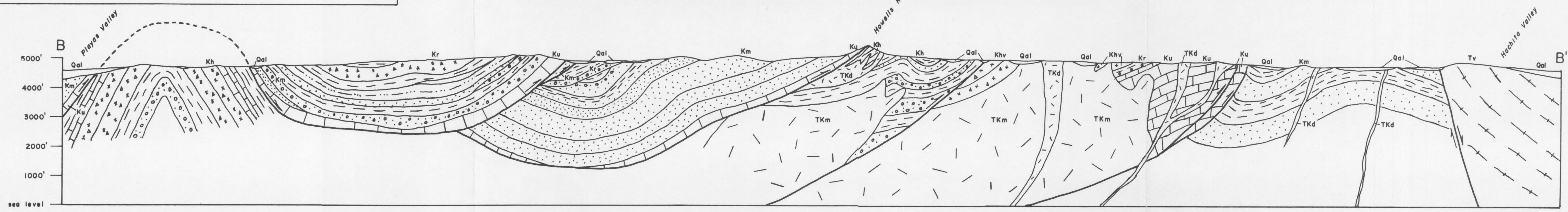
1 0 5 Miles

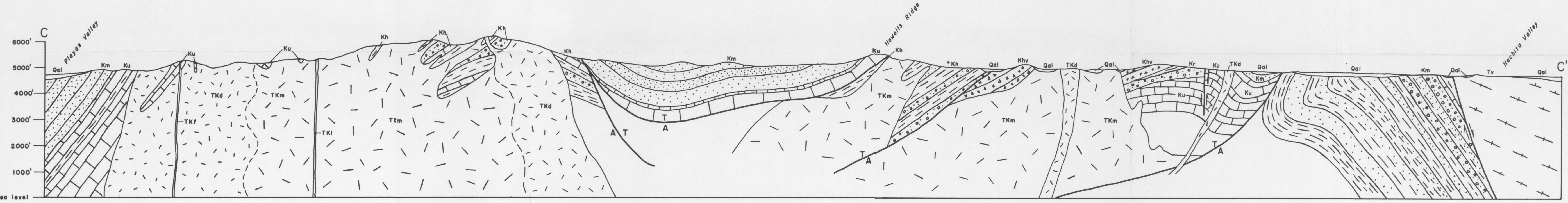
Contour interval 25 feet
*Datum is mean sea level*

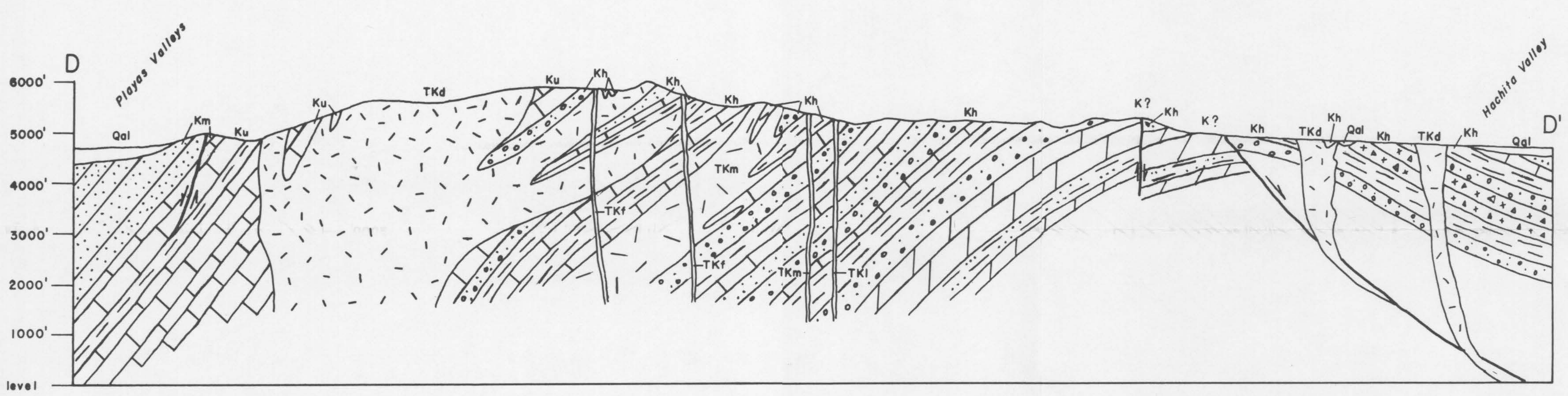
ROBERT A. ZELLER, JR.
1967

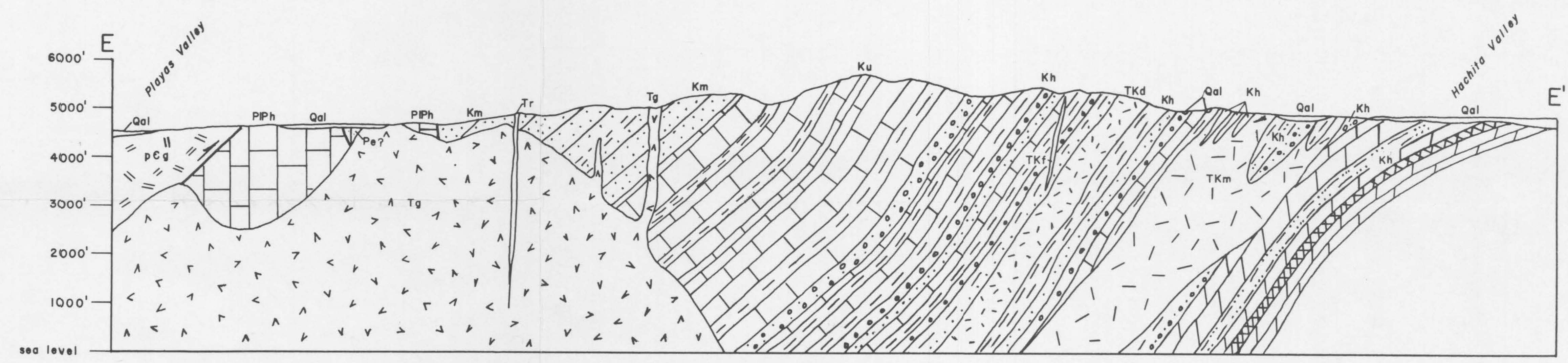



# GEOLOGIC CROSS SECTIONS OF THE LITTLE HATCHET MOUNTAINS, NEW MEXICO