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Geology of the Rinconada Canyon area, Valencia County, New Mexico.

John Mohar Jr.

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By

John Mohar, Jr.

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Geology

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

MASTER OF SCIENCE

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Thesis committee

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ABSTRACT

The Rinconada Canyon area is located about 65 miles west of Albuquerque on U. S. Highway 66 in the southern part of the Mount Taylor volcanic field.

Rocks of Cretaceous, Tertiary, and Quaternary ages crop out in the area. The Cretaceous rocks are represented by the Mancos shale and Mesaverde formations. They are characterized by thick sections of sandstone and shale, of both marine and non-marine origin, and some thin coal beds. These formations show the large-scale intertonguing relationships which record the transgressive and regressive phases of the Cretaceous seas.

The volcanic rocks in the area are of Tertiary and Quaternary ages. They are represented by a thick section of tuff-breccia, flows of porphyritic andesite, flows of basalt, and numerous dikes and volcanic plugs. Each type of igneous rock found in the area represents a different phase of activity in the Mount Taylor volcanic field.

Structurally the Rinconada Canyon area lies within the McCarty syncline, a border feature of the San Juan basin of northwestern New Mexico. Structural deformation in early Tertiary time folded the McCarty syncline. In middle Tertiary (?) time the folded strata were virtually

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leveled by erosion and upon this erosion surface was deposited the complex series of volcanic rocks which make up the Mount Taylor volcanic field.

Within this area are found two small domes superimposed upon the McCarty syncline. North dome, the larger of the two, is located at the head of Rinconada Canyon. South dome is located in the southern part of the area near the mouth of the canyon.

The joint systems on the two domal structures in the area provide a key to their formation. Relationships of the folded strata of the domes and the overlying volcanic rocks provide evidence that North dome is older than the eruptions of Mount Taylor, and South dome younger.

Model experiments performed as an aid to structural interpretation of South dome indicate the possibility of its formation being the result of an igneous intrusive mass rising at an angle of 40° to 45° from the horizontal.

Thus far the mineral resources of the area have been of little economic value. There are, however, large deposits of pumice and coal in the area and the possibility of a commercial uranium deposit at depth cannot be disregarded.

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INTRODUCTION

Location and Access

The area described in this report is in northwestern New Mexico about 65 miles west of Albuquerque. It consists of 45 square miles and lies between T.10 N. and T.11 N., R.7 W. and R.8 W. in north-central Valencia County. Rinconada Canyon drains the southwest slope of Mount Taylor and is a tributary of the Rio San Jose.

The area is readily accessible by road except for the high mesa tops along the northern and western sides. U. S. Highway 66 runs along the southern part of the area in the valley of the Rio San Jose. An all-weather gravel road three miles west of the village of San Fidel furnishes access to Rinconada Canyon and to San Fidel Mesa which lies along the southern flank of Mount Taylor. This road is joined by another which enters the area from the east and joins U. S. Highway 66 and the village of Cubero. Additional accessibility is supplied by numerous mining and logging roads in the area.

Relief and Drainage

The area is characterized by black basalt-capped mesas cut through by deep steep-sided canyons. The

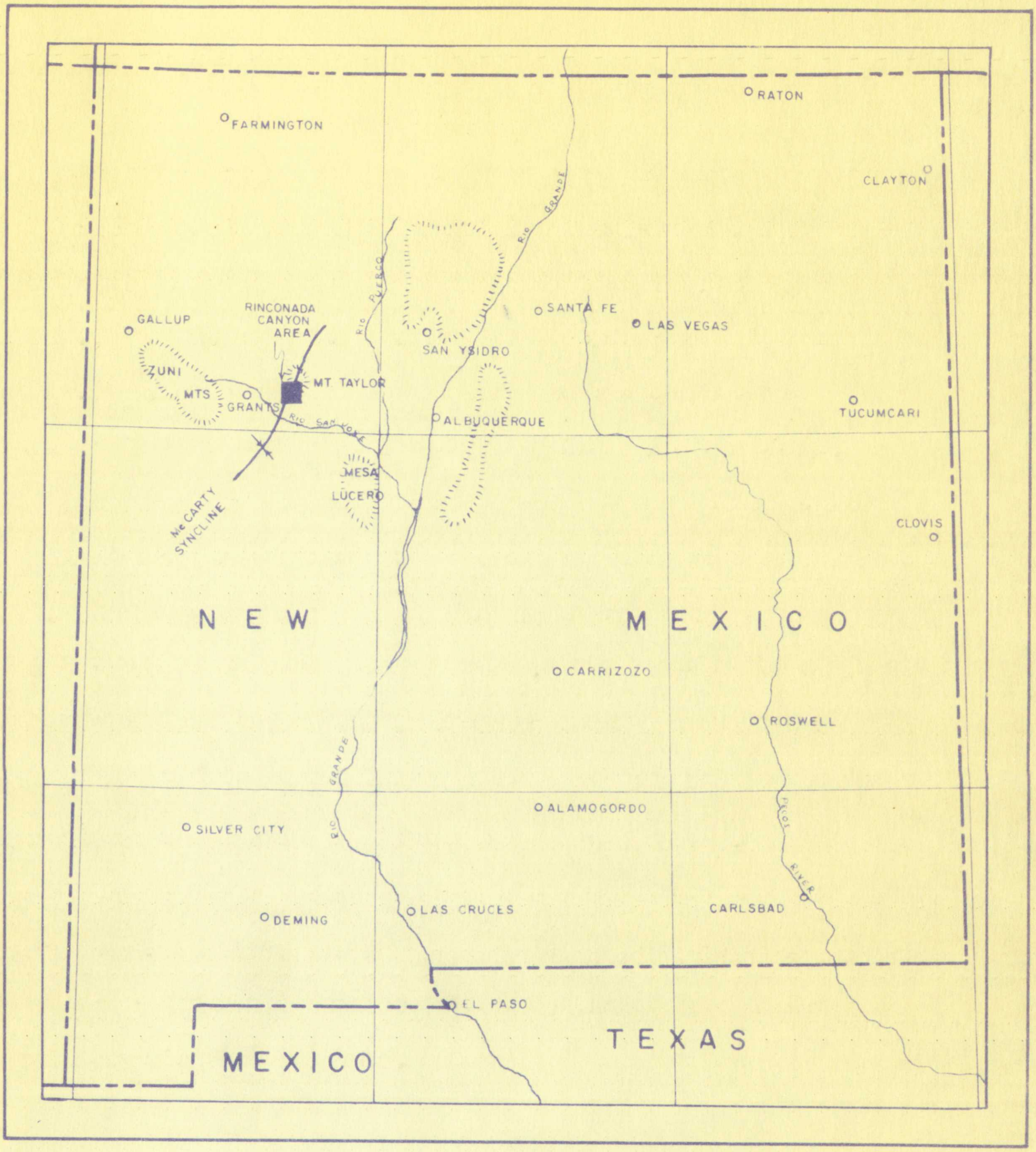

Figure I. Index map of New Mexico.

altitude ranges from 6160 feet in the valley of the Rio San Jose to more than 11,300 feet above sea level at the summit of Mount Taylor (Hunt, 1936, p. 36). Maximum relief in the Rinconada Canyon area is on the order of 2000 feet and is reached along the south side of San Fidel Mesa.

Rinconada Canyon and its tributaries constitute the primary drainage for the southwest slope of Mount Taylor. In it is found the only perennial stream of the area, which joins the eastward-flowing Rio San Jose between McCartys and San Fidel. Other streams carry water in the upper portions of the canyons cutting Mount Taylor and San Fidel Mesa but lose it by seepage and evaporation before they reach the Rio San Jose.

Climate and Vegetation

The climate of the area is semi-arid, with an average annual rainfall of about 14 inches. Mount Taylor, however, receives considerably more moisture because of its higher elevation. The vegetation in the lower valleys is characteristic of the Upper Sonoran life zone and consists mainly of grasses, juniper, pinon, and cacti. Thick stands of yellow pine are found in the higher elevations (Hunt, 1936, p. 37).

Previous Work

Several geologic studies have been made of the Mount Taylor region, particularly of the coal fields, and numerous descriptions of Mount Taylor itself can be found in the literature. Simpson (1850, p. 110) named Mount Taylor in honor of his president. Marcou (1856, p. 165-177) identified Mount Taylor as a volcano and on the basis of fossils assigned Jurassic and Cretaceous ages to the rocks in the valley of the Rio San Jose. In a later report (1858) Marcou produced the first geologic map and cross section of the area. Howell (1875, p. 227-301) described the folding of the Cretaceous strata as older than the Mount Taylor eruptions and the sheet basalt as younger. Dutton (1885, p. 105-198) gave a general discussion of the volcanic rocks with only brief mention of the sedimentary rocks. Darton (1928, p. 109-137) discussed the regional structural relationships of the area. Hunt (1936) made a study of the Mount Taylor coal field, and in a later paper (1938) described the volcanic rocks fully.

Present Investigation

The field work for this report was started in

September, 1955, and was continued until February, 1956. A geologic map was prepared on a scale of 1:31,680, control being supplied by aerial photographs, semi-controlled aerial mosaics and Soil Conservation Service planimetric map N. M. 174. Rock and mineral specimens were studied with the aid of hand lens and binocular microscope. Model experiments were made in the laboratory and recorded photographically. These experiments were carried out for use as an aid in interpreting structural relationships in the field area.

Acknowledgments

The writer wishes to thank Dr. V. C. Kelley of the University of New Mexico Geology Department for his aid in the selection of the problem and for his guidance and advice during the preparation of this report. Thanks are also due to Drs. J. P. Fitzsimmons and S. A. Wengerd for serving as members of the thesis committee, and to the Tide Water Associated Oil Co. and Mr. D. B. Hurley for the use of company facilities and equipment and for many valuable suggestions.

September, 1959, and was continued until [illegible], 1960. A geologic map was prepared on a scale of 1:24,000, control being supplied by aerial photographs, semi-controlled aerial mosaics and Soil Conservation Service planimetric map N. M. 171. Rock and mineral specimens were studied with the aid of hand lens and binocular microscope. Model experiments were made in the laboratory and recorded photographically. These experiments were carried out for use as an aid in interpreting structural relationships in the field area.

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STRATIGRAPHY

General Statement

The rocks of the Rinconada Canyon-Mount Taylor area range in age from Precambrian to Recent. Rocks older than Cretaceous do not crop out in the area covered by this report; however, they are found to the south and west. In a well drilled approximately 10 miles southwest of Rinconada Canyon the rocks range from Precambrian granite to Recent basalt with the granite being unconformably overlain by a thin Pennsylvanian section (S. A. Wengerd, oral communication, 1956).

The Mancos shale of Cretaceous age is the oldest formation outcropping in the area of this report. It is found in the valley of the Rio San Jose and is exposed for a short distance up Rinconada Canyon. The Mancos shale is overlain by the Mesaverde formation which is exposed in the sides of Rinconada Canyon and its tributaries and is capped by thick layers of Tertiary tuff-breccia, porphyritic andesite, and basalt. Quaternary rocks exposed in the Rinconada Canyon area include dikes, small plugs, landslide and valley alluvium deposits.

Cretaceous Rocks

Introductory Statement

The rocks of Cretaceous age outcropping in the Rinconada Canyon area are represented by the Mancos shale and the Mesaverde formation. These formations are characterized by large-scale intertonguing of marine and non-marine deposits. The two formations are differentiated on the basis of their lithologic character alone, the Mancos being predominantly a fissile, carbonaceous shale and the Mesaverde an alternating series of irregularly bedded sandstone, shale, and coal. The Mancos is a marine deposit and the Mesaverde is mostly a continental deposit.

Intertonguing Marine and Non-Marine Sediments

The Upper Cretaceous rocks of this region were deposited in a broad trough that extended in a northerly direction for several thousand miles and was about a thousand miles wide. During most of the period the center or deeper part of the trough was occupied by a shallow sea of irregular size and shape. At times this sea would enlarge and encroach upon the gentle slopes of the adjoining land and later withdraw into the deeper part of the trough (Sears, Hunt, and Hendricks, 1941, p. 102).

A record of these advances and retreats of the sea is shown by the intertonguing relationships of the Mancos shale and Mesaverde formation.

The first transgressive phase of the sea over the existing deposits of the adjoining land formed the beach and lagoonal deposits of the Dakota sandstone. As the sea encroached farther upon the land the older portions were covered by deepening water and were buried under the clays and silts of the Mancos shale. After a considerable time the sea began a regressive phase with near-shore and beach sand being deposited over the previously deposited marine muds, thus forming the Gallup sandstone member of the Mesaverde formation. As the sea retreated lagoons and coastal swamps formed along its margins. In these were deposited the irregular bodies of sand, clay, and organic material which make up the Dilco coal member of the Mesaverde formation.

Before the sea had retreated very far it began another transgressive phase, advancing over the near-shore and continental deposits of the preceding regressive phase. The deposition of Mancos muds had continued in the deeper parts of the sea throughout the regressive phase and with the new advance of the sea, marine muds of the Mancos shale, the Mulatto tongue, were laid down

A record of these [illegible] is shown by the [illegible] Mancos shale and Mesaverde formation.

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transgressively over the earlier sands of the Dilco coal member. Again as before the sea retreated forming near-shore and beach sand deposits which became the Dalton sandstone member of the Mesaverde formation. Also coastal lagoons and swamps again formed along the margins of the retreating sea giving rise to the lower part of the Gibson coal member.

The cycle was again repeated but at a somewhat slower rate. As the sea advanced sands were deposited, forming the lower part of the Hosta sandstone, and as the water deepened the marine muds of the Satan tongue of the Mancos were deposited over the earlier sands. After this transgression was complete there began the last of the regressive movements of the sea in this region. The sequence was essentially the same as before with the sands of the upper part of the Hosta sandstone covering the Satan tongue and in turn being covered by the lagoonal and swamp deposits of the upper part of the Gibson coal member.

During the last two regressive phases continental floodplain deposits were laid down over the coal beds and are represented by the Bartlett and Allison barren members of the Mesaverde formation (Sears, Hunt, and Hendricks, 1941, p. 115-120).

Two views were offered by Pike (1947) in explanation

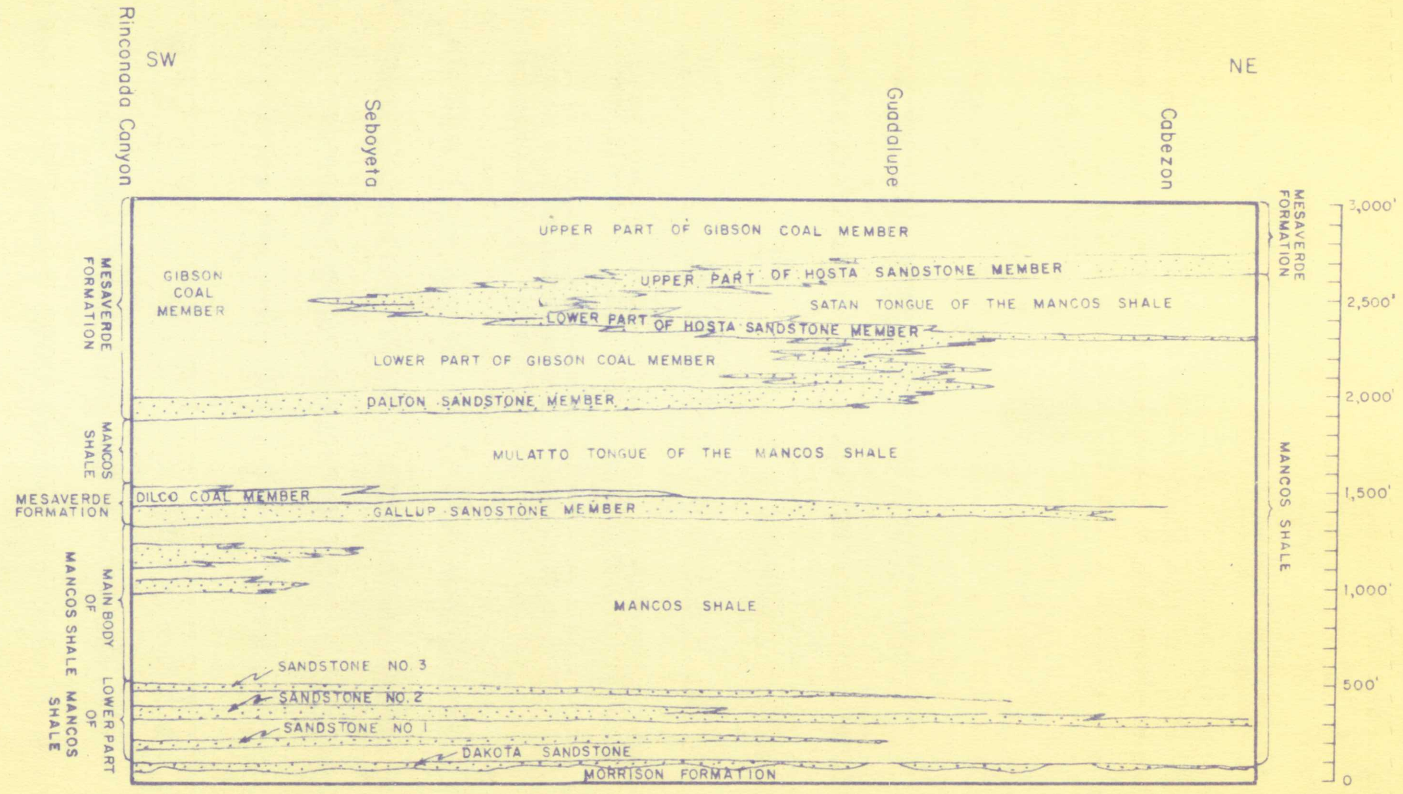

Figure 2. Diagrammatic section illustrating intertonguing relations of the Mancos and Mesaverde formations. (After Hunt, 1936)

of the causes of these oscillations of the Upper Cretaceous epicontinental seas. The first theory postulates a raising and lowering of the trough of deposition, whereas the second theory holds that both transgression and regression may take place in a continuously sinking basin of deposition with a change in the rate of supply of detritus.

Mancos Shale

The Mancos shale was named by Cross (1899a, p. 4) from exposures near the town of Mancos, Colorado. In a later paper (1899b, p. 4) he described it as being

> "an almost homogeneous body of soft, dark gray or nearly black, carbonaceous clay shale, varied only by the presence of a few thin bands or concretions of impure limestone....It is limited below by the Dakota sandstone and above by the lowest sandstone of the Mesaverde formation of alternating sandstones and shales."

At the type locality Cross estimated a thickness of 1200 feet; however, only 4 or 5 miles away a thickness of 2191 feet has been measured and in western Colorado the thickness reaches 6000 feet (Pike, 1947, p. 9).

Main Body of the Mancos Shale.—In the Rinconada Canyon area the main body of the Mancos shale attains a thickness of about 1200 feet. It consists of dark gray to nearly black carbonaceous shale which becomes increasingly calcareous near the top. Many thin-bedded,

of the cause of these oscillations of the Upper Cretaceous seas, Weimer (1960, [illegible]). The first theory postulates a rhythmic and irregular uplift of source of deposition, whereas the second theory holds that both transgression and regression may take place in a continuously sinking basin of deposition with a change in the rate of supply of detritus.

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Main Body of the Mancos Shale.--In the [illegible] Canyon area the main body of the Mancos shale has a thickness of about 1200 feet. It consists of [illegible] to nearly black carbonaceous shale which becomes increasingly calcareous toward the base. [illegible]

light-colored, calcareous sandstone beds are found throughout the section. In the upper part there are found numerous fossil horizons. The fossils are found mainly in the sandstone, but some may be found in the shale as well.

Mulatto Tongue.--The Mulatto tongue of the Mancos shale lies between the Dilco coal member and the Dalton sandstone member of the Mesaverde formation. It was named by Hunt (1936, p. 44) for exposures at Canyon Mulatto, nine miles northwest of San Mateo.

In the Rinconada Canyon area the Mulatto tongue ranges in thickness from 200 feet along the west side of Guadalupe Canyon to almost 250 feet at the head of Rinconada Canyon. It is made up of light greenish-brown arenaceous shale interbedded with thin, light tan calcareous sandstone. Fossil remains are scarce but some fossils may be found in the lower few feet.

Mesaverde Formation

The term "Mesa Verde Group" was used by Holmes (1877, p. 244) to describe a series of rocks 1100 to 1200 feet thick exposed in what is now known as Mesa Verde National Park, in Montezuma County, Colorado. Three divisions were described by Holmes as the "Upper Escarpment sandstone", the "Middle Coal Group", and the "Lower Escarpment sandstone".

In the Rinconada Canyon area the Mesaverde formation is represented by coal beds and thick marine shale beds separated by non-marine sandstone beds. The total thickness in this area is 1240 feet, but a complete section is not present.

Gallup Sandstone Member.—The Gallup sandstone member of the Mesaverde formation was named by Sears (1925, p. 17) and consists of three or more beds of massive sandstone and interbedded shale and coal which outcrops near the town of Gallup. It is the basal member of the Mesaverde formation.

In this area the Gallup sandstone is made up of two massive sandstone beds separated by a thin shale bed. The lower sandstone is 59 feet thick and is composed of clean rounded quartz sand grains poorly cemented. It forms a prominent cliff with a sharp lithologic break from the underlying Mancos shale. This sandstone is overlain by a carbonaceous gray arenaceous shale 28 feet thick. The upper sandstone has a thickness of 63 feet and is very much like the lower one. The upper surface of this sandstone weathers into very characteristic hummocky or "beehive" forms.

Dilco Coal Member.—The Dilco coal member of the Mesaverde formation is a continental deposit formed

In the Rinconada Canyon area the Mesaverde formation is represented by [illegible] shale and thick white [illegible] separated by non-marine sandstone beds. The total thickness in this area is 128 feet, but a complete section is not present.

Gallup Sandstone Member.—The Gallup sandstone member of the Mesaverde formation was named by Sears (1925, p. 17) and consists of three or more beds of massive sandstones and interbedded shale and coal which outcrops near the town of Gallup. It is the basal member of the Mesaverde formation.

In this area the Gallup sandstone is made up of two massive sandstone beds separated by a thin coaly bed. The lower sandstone is 53 feet thick and is composed of clean rounded quartz and is poorly cemented. It forms a prominent cliff with a sharp distinct break from the underlying Mancos shale. This sandstone is overlain by a carbonaceous gray Mancos shale 20 feet thick. The upper sandstone has a thickness of 60 feet and is very much like the lower one. The upper surface of this sandstone weathers into a very characteristic hummocky or "castle" form.

Dilco Coal Member.—The Dilco coal member of the Mesaverde formation is a continental deposit of coal

during a regressive stage of the sea. It reaches its maximum thickness of about 300 feet in the Gallup area where it is an important coal producer. It is characterized by irregular sandstone beds, light-colored to dark gray carbonaceous shale, and lenticular coal beds, some of which locally reach a thickness of five feet or more (Sears, 1934, p. 16).

In the Rinconada Canyon area the Dilco does not contain any coal beds and is made up entirely of continental sand and clay. In this area it has a total thickness of 175 feet. It is characterized by three distinct lithologic zones. The lower zone is 90 feet thick and is a sandy, carbonaceous shale within which are numerous thin-bedded[1] sandstone stringers 1 to 4 inches in thickness. The second zone is a tan, thick-bedded, argillaceous sandstone 19 feet thick which forms a prominent cliff along the canyon walls. The top zone is very irregular. It is represented by alternating medium-bedded sandstone and very thin shale beds. It is 66 feet thick and usually forms a cliff. Apparently this upper part of the Dilco represents a transition zone into the overlying Mulatto tongue of the Mancos shale and is the result of minor fluctuations of the encroaching sea.

1. Here as elsewhere the following beddedness terms are used: Thin-bedded, 1 inch to 1 foot thick; medium-bedded, 1-3 feet thick; thick-bedded, 3-6 feet thick; massive, 6 feet thick or more.

during a regressive stage of this sea. It reaches its maximum thickness of about 300 feet in the [illegible] where it is an important coal [illegible]. It is characterized by irregular sandstone units, light-colored to dark grey carbonaceous shale, and lenticular coal beds, some of which locally reach a thickness of [illegible] feet or more (Sears, 1934, p. 16).

In the Rinconada Canyon area the [illegible] does not contain any coal beds and is made up entirely of [illegible] and [illegible]. It has a total thickness of 175 feet. It is characterized by three distinct lithologic zones. The lower zone, [illegible] feet thick, is a sandy, carbonaceous shale within which are numerous thin-bedded sandstones, from 1 to 4 inches in thickness. The second zone is a [illegible] sandstone 19 feet thick which forms a prominent cliff along the canyon walls. The top zone is very irregular. It is represented by alternating medium-bedded sandstone and very thin shale beds. It is [illegible] feet thick and usually forms a cliff. Apparently this upper part of the unit represents a transitional zone from the [illegible] tongue of the Mancos shale and is the result of minor fluctuations of the [illegible] sea.

1. [illegible]

Dalton Sandstone Member.—The Dalton sandstone was named by Sears (1934, p. 17) from excellent exposures at Dalton Pass, nine miles west of Crown Point. It is a very conspicuous, massive, cliff-forming sandstone.

In the area of this investigation it has a very uniform thickness of 115 feet. It is represented by two massive, light tan sandstone beds composed of clean, rounded quartz grains. The two beds are separated by a 7-foot to 10-foot interval of light gray arenaceous shale with some sandstone stringers up to six inches in thickness. These sandstone beds show conspicuous channeling and cross-bedding and increase in grain size from medium-grained quartz at the base to coarse-grained at the top.

The Dalton forms prominent benches along the canyon walls, particularly in Guadalupe Canyon where they extend out several hundred yards, forming table-like projections. It weathers into distinctive blocky forms on the surface making it easily identifiable in the field.

Gibson Coal Member.—The Gibson coal member of the Mesaverde formation was named and described by Sears (1925, p. 17) from exposures near the village of Gibson. Here the Gibson consists of two parts, the upper and the lower, separated by the Hosta sandstone. According to Sears, Hunt, and Hendricks (1941, p. 114) the maximum

Dalton Sandstone Member.—The Dalton Sandstone was named by Sears (1934, p. [illegible]) from its [illegible] exposures at Dalton Pass, nine miles west of Crownpoint. It is a very conspicuous, steep [illegible]-forming [illegible].

To the east of [illegible] the Dalton [illegible] a very uniform thickness of 115 feet, and is composed of two massive, light [illegible] sandstone [illegible] pounded [illegible]. The [illegible] a 7-foot to 10-foot [illegible] shale with some sand [illegible] thickness. [illegible] channelling and cross-bedding [illegible] from [illegible] at the base.

The Dalton forms prominent [illegible] walls, particularly [illegible] out several hundred yards, [illegible]. It weathers [illegible] making it easily identifiable in the field.

Gibson Coal Member.—[illegible] Mesaverde formation [illegible] (1925, p. 17) [illegible]. Here the Gibson [illegible] the lower, separated by the [illegible]. According to Sears, Hunt, and Hendricks (1941, p. 114) [illegible]

Plate 1. View of Gibson coal member showing pinch-out of sandstone bed.

thickness of the lower part of the Gibson is 300 feet and the upper part 150 feet.

In the Rinconada Canyon area, according to Hunt (1936, p. 48), the Hosta sandstone is not recognizable, and hence the Gibson has not been divided into lower and upper parts. In this area the exposed thickness is 550 feet but the total thickness probably exceeds this figure somewhat. After careful examination of the Gibson by the writer it is believed that the Hosta is entirely absent in this area probably owing to the fact that it was marginal to this phase of the transgressive sea. The abnormal thickness of the Gibson in this area indicates that the area was the site of continued continental and swamp deposition during the time when the Hosta sandstone and Satan tongue of the Mancos shale were being deposited to the north and east.

In this area the Gibson is represented by alternating shale, carbonaceous shale, sandstone, and coal beds. The sandstone beds are very lenticular (Pl. 1) grading laterally into shale and coal beds. The sandstone beds are usually light in color and contain numerous hematitic concretions. Locally where they overlie coal beds plant fossils are present along the contact.

In Guadalupe Canyon several coal beds are exposed in the lower 300 feet of the Gibson and have been mined

in a small way. The coal is of subbituminous rank and individual beds reach a thickness of five feet. They are very irregular and do not extend laterally for any great distance.

Tertiary Rocks

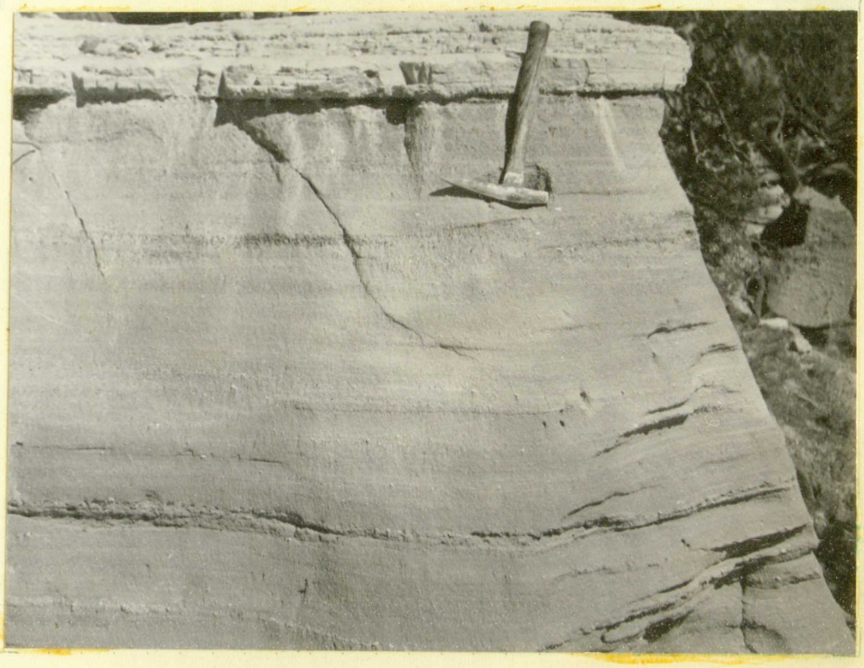
Introductory Statement

The exposed rocks of Tertiary age in this area are all igneous and are of several types. These are tuff-breccia, porphyritic andesite flows, basaltic dikes and plugs, and basaltic flows. The tuff-breccia and porphyritic andesite are the result of eruptions from Mount Taylor. The basalt was extruded from vents and fissures around Mount Taylor after the central eruptions had ceased (Hunt, 1938). At the head of Rinconada Canyon the sheet basalt can be seen overlying the porphyritic andesite from Mount Taylor; however, it is impossible to trace the extent of this overlap across the mesas.

Tuff-breccia

The tuff-breccia in this area rests on an erosion surface which truncates the gently northward-dipping strata of the Mesaverde formation. It may be divided into four stratigraphic intervals. At the base is a massive unit 157 feet thick that is composed principally of pumice fragments in a matrix of volcanic dust. There

Plate 2.



A. Stratified tuff.

B. Contact between stratified and overlying unstratified tuff-breccia.

are also found in this unit a few lapilli, small bombs, and obsidian fragments. There is a complete lack of sorting of the material and it is undoubtedly of pyroclastic origin.

Overlying the unstratified breccia is an interval of 38 feet of stratified breccia. It consists of well-rounded pebbles of pumice with some pebbles and cobbles of red sandstone, basalt, andesite, and granite. This is overlain by another massive unit much like the first except that it contains a larger proportion of lapilli and some rock fragments.

The top layer is a stratified zone 179 feet in thickness. It is well stratified, but sorting is poor and it contains many rock fragments. Near the top of this unit are layers which are made up almost entirely of lapilli and small bombs. The upper 3 to 5 feet of the breccia has been baked a brick red by the overlying basalt.

Porphyritic Andesite

The porphyritic andesite in this area was extruded in one of the last stages in the Mount Taylor eruptions. The andesite was not poured out from the central vent but from radiating dikes immediately around it (Hunt, 1938, p. 62).

In the area of this report porphyritic andesite is found only at the head of Rinconada Canyon where it is overlain by sheet basalt. At this exposure the andesite apparently consists of two flows with a total thickness of approximately 100 feet. It is highly scoriaceous near the base and at the top, and has a very irregular columnar jointing. It contains phenocrysts of andesine and some olivine.

Basalt

Extrusion of basalt was the last phase of activity in the Mount Taylor volcanic field. It was erupted from numerous small vents and fissures around Mount Taylor. The basalt flowed on erosion surfaces developed around the base of Mount Taylor and is found capping many of the mesas in this area.

Basalt flows cap the mesas surrounding Rinconada Canyon and its tributaries. They range in thickness from 30 to 75 feet and are irregularly jointed. At the head of Rinconada Canyon the basalt overlaps the earlier flows of porphyritic andesite from Mount Taylor.

Dikes and Plugs

Numerous dikes and volcanic plugs are exposed in the Mount Taylor volcanic field. They stand as resistant

masses above the more easily eroded sedimentary strata.

In the Rinconada Canyon area are found two plugs and a dike, of basaltic composition, which represent probable centers for the extrusion of the basalt flows. The dike, about 30 feet wide, was intruded along a fault. This dike is located near the mouth of Rinconada Canyon and follows a fault which displaces the Cretaceous sandstone and shale 150 feet. Hunt (1938, p. 72) states:

> "This is the only known locality in the Mount Taylor volcanic field where a dike follows a fault fissure. The occurrence is also unusual for this field in that the basalt is relatively very coarsely crystalline and could be described as dolerite. It is composed of sodic labradorite, augite, and minor quantities of olivine and magnetite."

Quaternary Rocks

Basalt

The only Recent basalt is the McCartys flow and is found in the valley of the Rio San Jose. The source of this flow was not in the Mount Taylor volcanic field but originated from a small vent about 20 miles to the southwest (Nichols, 1946, p. 1052).

One basaltic dike of Quaternary age is found on the west side of Rinconada Canyon near its head. It cuts through the Tertiary mesa-capping basalt and forms a low ridge across the flow for a short distance.

Valley Alluvium

The alluvium is confined to the valleys. It consists mostly of alluvial fans and terrace gravels. The fragments range in size from silt to large boulders and are made up of fragments of pumice, perlite, basalt, granite, and sedimentary rocks.

Landslides and Talus

Landslide and talus deposits are confined to the steeper slopes which are underlain by shale of the Mesaverde formation. The shale is easily eroded thereby undermining the basalt cap which breaks off and slides downslope. Some slopes in the area are completely covered by these slide-blocks.

STRUCTURE

Regional Setting

The area of this report lies near the southern border of the San Juan basin of the Colorado Plateau Province. The San Juan basin is located in northwestern New Mexico and adjoining parts of Colorado. It is a broad structural basin surrounded by low uplifts. The northern, eastern, and western boundries of the basin are marked by domal uplifts, monoclinal bends, and thrust faults. The southern boundary is not so clearly defined, being an area of low structural platforms and broad structural embayments.

The present structural elements found in and associated with the San Juan basin were developed during late Cretaceous and early Tertiary time; however, its tectonic evolution began as early as late Paleozoic time (Kelley, 1951, p. 130).

The south flank of the basin, on which the Rinconada Canyon area is located, exhibits a gentle northward dip derived from the deformation of the Zuni and Lucero uplifts. Two northward-plunging synclines flank the Zuni uplift, the Gallup-Zuni basin on the west and the McCarty syncline on the east. The Zuni and Lucero uplifts

are also separated by a broad structural embayment of the San Juan basin called the Acoma embayment (Kelley, 1951, p. 130).

Faults

Faults in the Rinconada Canyon area are small both in linear extent and in displacement. All the faults are normal and nearly vertical. The ages of the faults vary considerably. The oldest faults in the area are those located on North dome at the head of Rinconada Canyon. These faults are probably associated with the deformation which formed the McCarty syncline and North dome and therefore must be post-early Eocene and pre-late Miocene in age (Hunt, 1938, p. 74). Another fault, in sec. 27, T.11 N., R.8 W. displaces the Mesaverde beds approximately 150 feet down to the east. This fault is unique in being the only known locality in the Mount Taylor volcanic field where a dike follows a fault fissure. At the southern end of the fault is a small volcanic plug. This fissure and plug probably contributed to the basalt that now caps the mesas in the area. No evidence can be found to indicate that the fault cuts the tuff-breccia and hence must be older than the eruptions of Mount Taylor.

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Faults in the Rinconada Canyon area are small both in linear extent and in displacement. All the faults are normal and nearly vertical. The ages of the faults vary considerably. The oldest faults in the area are those located on North Dome at the head of Rinconada Canyon. These faults are probably associated with the deformation which formed the [illegible] and therefore must be post-early Eocene and pre-late Miocene in age (Hunt, 1938, p. 77). Another fault, in sec. 27, T.11 N., R.5 W. displaces the [illegible] beds approximately 150 feet down to the south. This fault is unique in being the only known locality in the Mount Taylor volcanic field where a dike follows a fault fissure. At the southern end of the fault is a small volcanic plug. This fissure and plug probably connected with the basalt that now caps the mesa in the area. No evidence can be found to indicate that the fault cuts the basalt - flows and hence must be older than the eruptions of Mount Taylor.

All faults in the area other than those mentioned above are of younger age than the eruptions of sheet basalt around Mount Taylor. Two northeasterly trending faults are found along the eastern side of Horace Mesa, one in Sec. 4, T.10 N., R.8 W. and one in Secs. 16 and 21, T.11 N., R.8W., each has a displacement of about 50 feet down on the southwest. These faults cut the basalt cap of the mesa and are probably related to more recent structural deformation in the area.

The remaining faults in the area are located on South dome, the most recent structure in the area, and are probably related to its formation. These are normal faults with small displacements and are arranged in a radial pattern from the crest of the dome. They are undoubtedly the result of tensional stresses developed during the formation of the dome.

Folds

General Statement

The major fold in the area is the northeasterly trending McCarty syncline, in the trough of which lies the area of this report. The McCarty syncline, south of the Mount Taylor volcanic field, is shallow, with structural relief of 600 feet. Near Mount Taylor it becomes strongly asymmetric with structural relief of

1500 feet and plunges gradually beneath Mount Taylor. The west flank of the syncline is very steep and appears as a hogback which can be traced from just east of Grants almost 15 miles to the northeast. The east flank is very regular and dips westward at about 200 feet to the mile (Hunt, 1938, p. 74).

In the Rinconada Canyon area are found two domal structures which are superimposed on the McCarty syncline. At the head of Rinconada Canyon, in the eastern part of T.11 N., R.8 W., is a dome that is about two square miles in size with a structural relief of about 1000 feet. This dome is referred to in this report as North dome. The second dome, somewhat smaller in size than the first, is located in Sec. 36, T.11 N., R.8 W. and is referred to in this report as South dome.

North Dome

North dome is an elliptical structure at the head of Rinconada Canyon. Hunt (1938, p. 74) finds it puzzling that this dome and another to the west in Lobo Canyon occur at the heads of the two largest canyons in the area. He states that:

> "It would seem reasonable to interpret these domes as later than the lavas, including the sheet basalts, and also to regard the canyons as having been eroded because of the disruption of the resistant lava cap. ...No direct evidence was found indicating that the two folds are later than the eruptions capping the canyon rims."

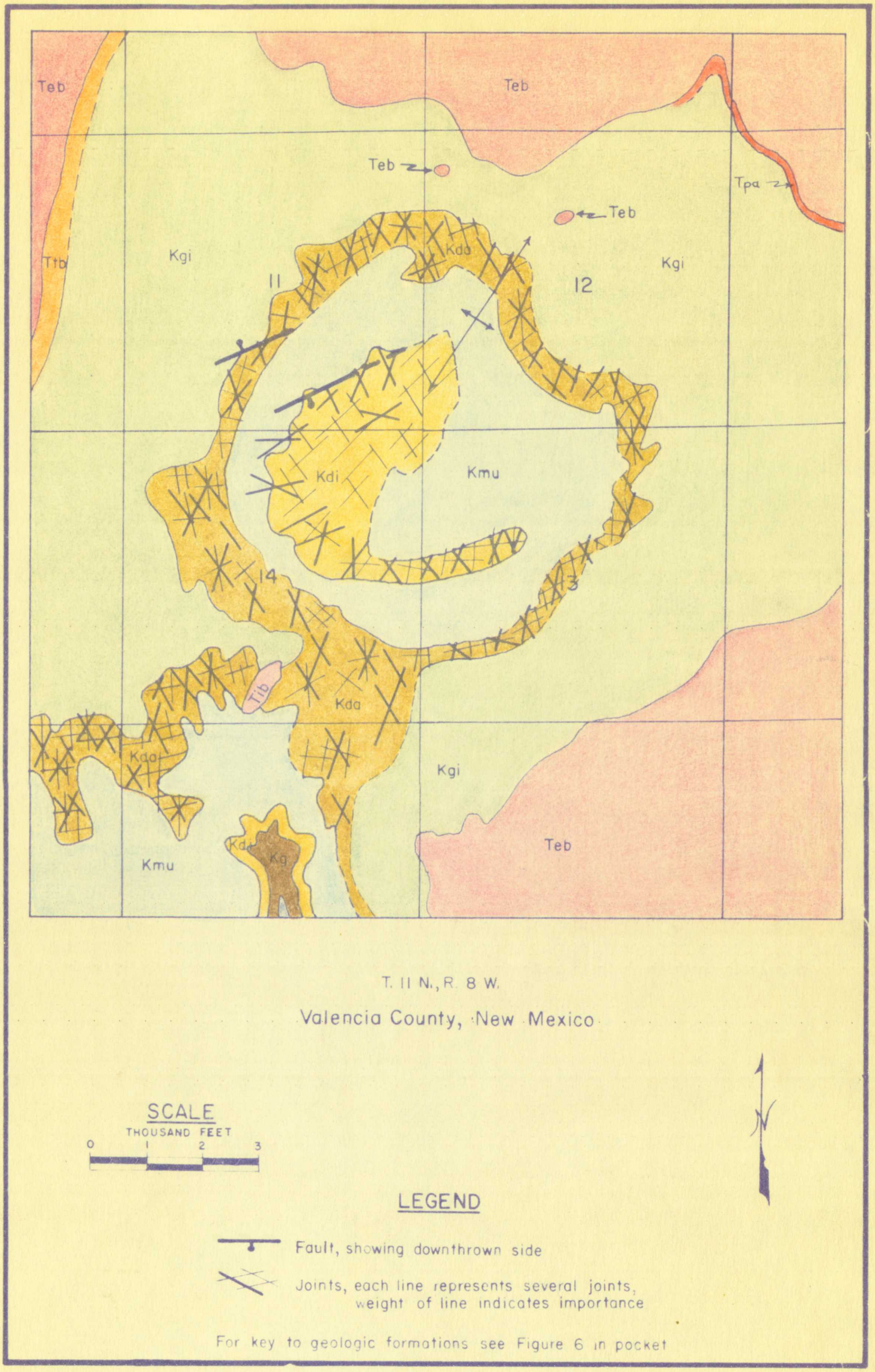

Figure 3. Joint systems on North dome.

This dome is highly symmetrical with quaquaversal dips of 15° to 20°. Along the rim of the canyon the folded sandstone and shale beds of the Gibson member of the Mesaverde formation are truncated by the erosion surface upon which the basalt cap rests. From this evidence it is apparent that the folding occurred a considerable time before the eruption of Mount Taylor to allow time for the development of this almost flat erosion surface.

The joint systems were mapped in the Dilco and Dalton members of the Mesaverde formation on North dome and are shown in Figure 3. From a study of these joints it seems apparent that the major joint system consists of two sets of joints, one set which strikes in a northeasterly direction and another set which strikes in a northwesterly direction. This system of joints is apparently the result of horizontal compressional forces operating in an east-west direction with the direction of easiest relief being in a north-south direction. The second system of joints, less prominent than the first, consists of one set of joints arranged radially around the dome and another set which is normal to the first. This system of joints is the result of tensional stresses developed when the rocks were domed.

From the evidence thus presented it is the belief of the writer that the formation of North dome was contemporaneous with the McCarty syncline and resulted from compressional forces that were developed in the folding of the syncline within which it lies. The compressional stresses which formed the dome were operative at right angles to the axis of the syncline with the direction of easiest relief being parallel to the axis. This accounts for the slight elongation of the dome parallel to the axis of the syncline.

South Dome

South dome is a highly asymmetrical structure, nearly circular in outcrop, found in the southern part of the area. Hunt (1938, p. 75) states that:

> "A remarkable feature of the dome in the southwestern part of T.11 N., R.8 W., is the abrupt flexure of the west flank. There is no intermediate dip between the flat beds to the west and the nearly vertical beds of the west flank. This abrupt change in dip and the fact that these domes produce considerable structural relief within very small areas suggest forces of igneous injections, but no evidence was found of alteration or baking of the beds on the crests of the domes."

The west and south flanks of this dome are very steep with dips ranging from 80° to 85°. In a small canyon which breaches the dome on the south side, in a distance of 20 yards, the Dilco coal member of the Mesaverde formation

From the evidence thus presented it is the opinion of the writer that the formation of North dome was contemporaneous with the [illegible] syncline and resulted from compressional forces that were developed in the folding of the syncline within which it lies. The compressional stresses [illegible] were operative at right angles to the axis of the syncline with the direction of easiest relief being parallel to the axis. This accounts for the slight elongation of the dome parallel to the axis of the syncline.

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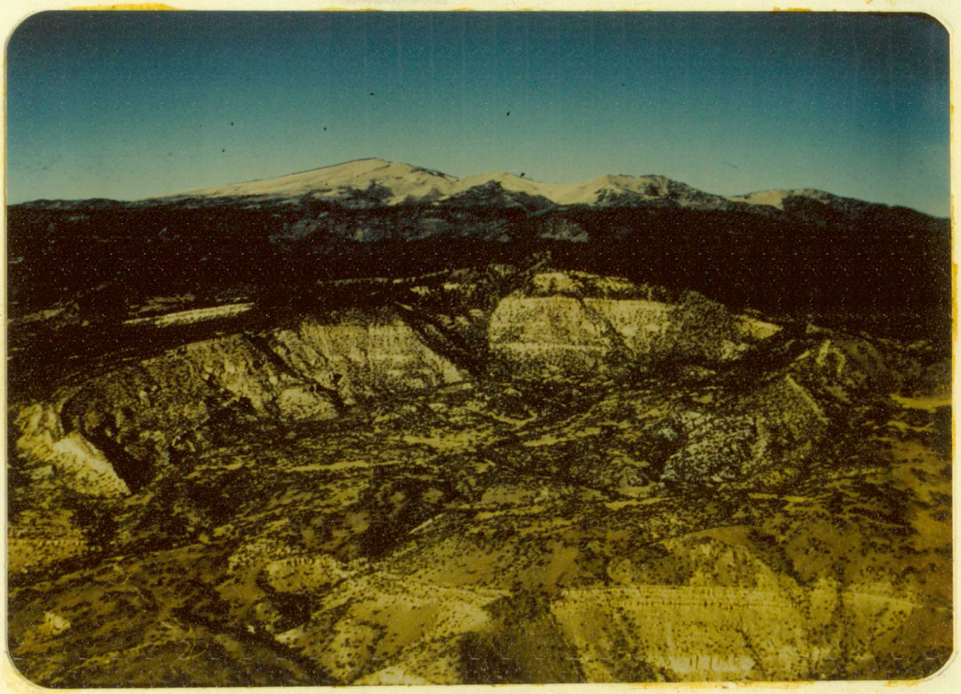
South dome is a highly asymmetrical structure, nearly circular in outcrop, found in the southern part of the area. Hunt (1938, p. 75) states that:

> "A remarkable feature of the dome in the southwestern part of T.11 N., R.10 W., is the abrupt flexure of the west flank. There is no intermediate dip between the flat beds of the crest and the nearly vertical beds of the west flank. This abrupt change in dip and the fact that these domes produce considerable structural relief within very small areas suggest the effects of igneous intrusions, but no evidence was found of intrusion or baking of the rocks on the crests of the domes."

The west and south flanks of this dome are very steep with dips ranging from 50° to 85°. In a small canyon which breaches the dome on the south side, for a distance of 20 yards, the Dilco coal member of the Mesaverde formation



A

B

Plate 3. Aerial views of South dome.

A. View north across the dome toward Mount Taylor. Nearly vertical southwest limb, lower left.

B. View of the north limb showing involvement of the Pleistocene basalt flow (b) in the folding.

can be seen to change in dip from 5° northward to 82° to the south. This abrupt change is in marked contrast to the north and east flanks of the dome which dip uniformly away at 12° to 20°.

The joint systems found in the Dilco and Gallup members of the Mesaverde formation were mapped on the dome and are shown in Figure 4. The major joint system mapped is made up of typical tension joints with one set being arranged radially around the dome and the second set being normal to the first. Another system of joints is not so well developed and corresponds to the joints found in the other parts of the area. This joint system is probably related to the folding of the McCarty syncline.

South dome is unique in another respect. This structure is a comparatively recent feature as compared with other structural deformation found in the area. The Tertiary basalt cap on San Fidel Mesa has been domed up as a result of the formation of this dome.

From the evidence presented above it seems likely to the writer that South dome is the result of an intrusive igneous body punching up from depth. It also seems likely that due to the sharp bending of the beds on the south and west sides of the dome that the igneous body could not be more than a few tens of feet below the surface. If

can be seen to change in dip from 5° northward to 32° to the south. This abrupt change is in marked contrast to the north and east flanks of the dome which dip uniformly away at 12° to 20°.

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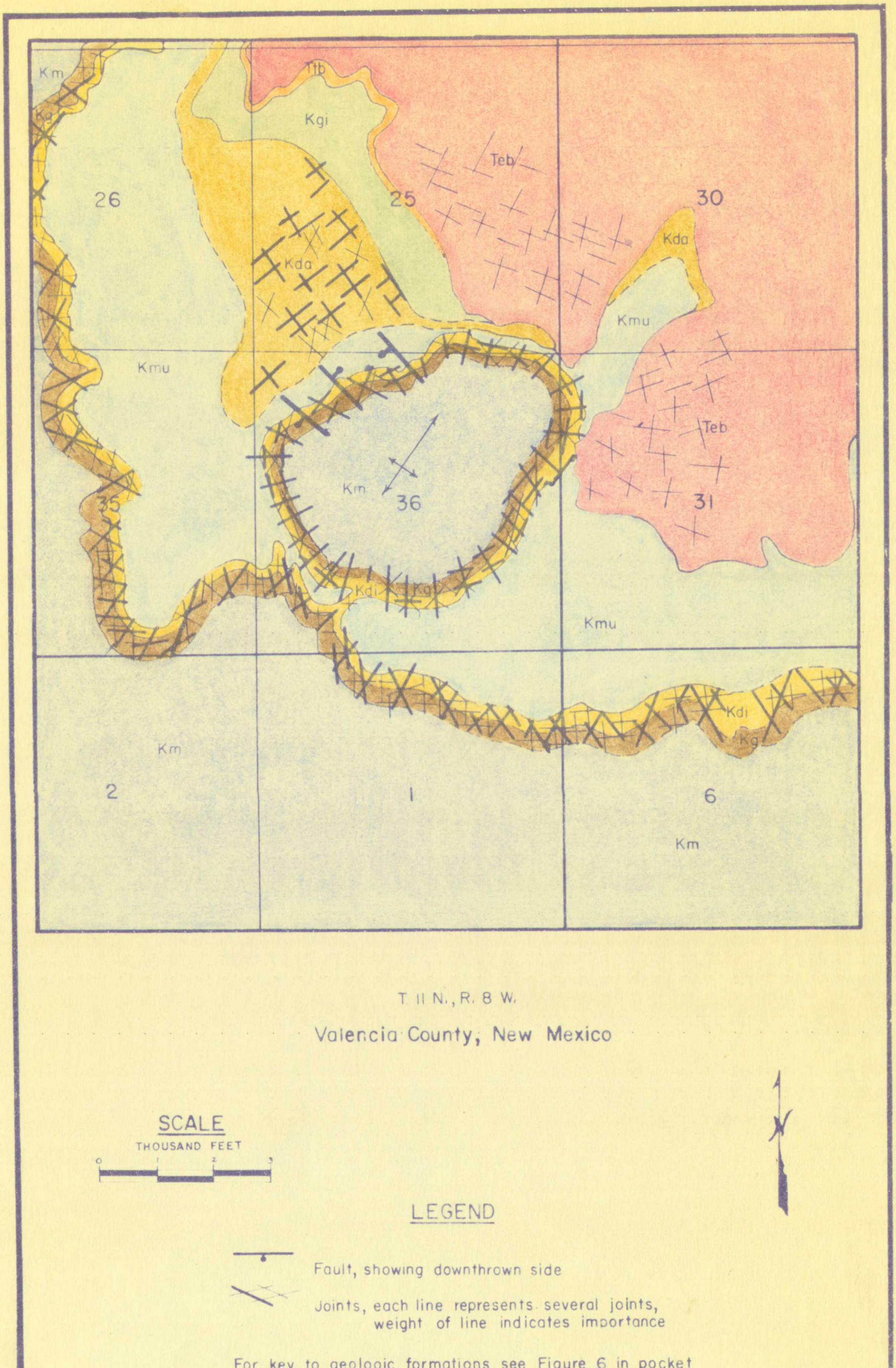


Figure 4. Joint systems on South dome.

it were at a greater depth it would not seem likely that so sharp a flexure would develop and one more gentle would be present. However, after further investigation it was found that the Carroll and Cornell State #1 wildcat had been drilled for oil just off the crest of the dome and penetrated 1167 feet of sedimentary rocks bottoming in the Morrison formation of Jurassic age.

Model Experiments.—Model experiments were undertaken in an effort to reach a satisfactory explanation of the conditions under which a structure with the characteristics of South dome could be formed. From the attitude of the strata around the dome it would seem possible that it could be the result of igneous injection, with the igneous body rising not vertically, but deviating to some extent from the vertical. The purpose of the model experiments was to determine, if possible, if an intrusive body punching through the strata at some angle from the vertical could produce features similar to those found on South dome, and if so, to determine what the angle might be and what might be the position of the intrusive at depth.

The model experiments are based primarily on the work done by Link (1930) and Parker and McDowell (1955). Link used sand and plaster of Paris to represent the

sedimentary beds and used several substances of varying plasticity to represent the intrusive mass. His experiments illustrate the fact that the more plastic the intrusive, the broader is the doming effect produced at the surface. The main conclusion drawn by Link (1930, p. 502) was

> "that an upward moving mass propelled by a force from below and unaided by tangential compression, cannot maintain its shape unless it is endowed with a rigidity greater than that of the surrounding country rock."

In his experiments using a rigid plug as an intrusive he produced small sharply defined domes with very steep flanks. Based on these results obtained by Link, the writer's opinion is that a rigid plug is more nearly suited to represent an igneous intrusive body than more plastic materials which would be used.

In the work of Parker and McDowell (1955, p. 2438) some parts of their experiments utilized a glass-fronted model filled with sand and a rigid plunger. They state that the strength of sand is too great for use as sedimentary strata in a model where the forces of injection are in scale to those found within the earth. However, by using a rigid plug to which an almost unlimited amount of force can be applied, the use of sand is entirely suitable in a model. The structures thus produced are essentially

the same as in their other experiments using more plastic materials and forces proportionately scaled down.

The writer constructed a model box which is 16 inches long, 8 inches high, and 6 inches wide. The box was fitted with a glass front so that the experiments could be easily observed and recorded photographically while in progress. Holes were drilled in the bottom of the box to accept a half-round hardwood plunger one inch in diameter. The plunger represents the intrusive igneous body. The flat side of the plunger was placed against the glass so maximum deformation could be observed.

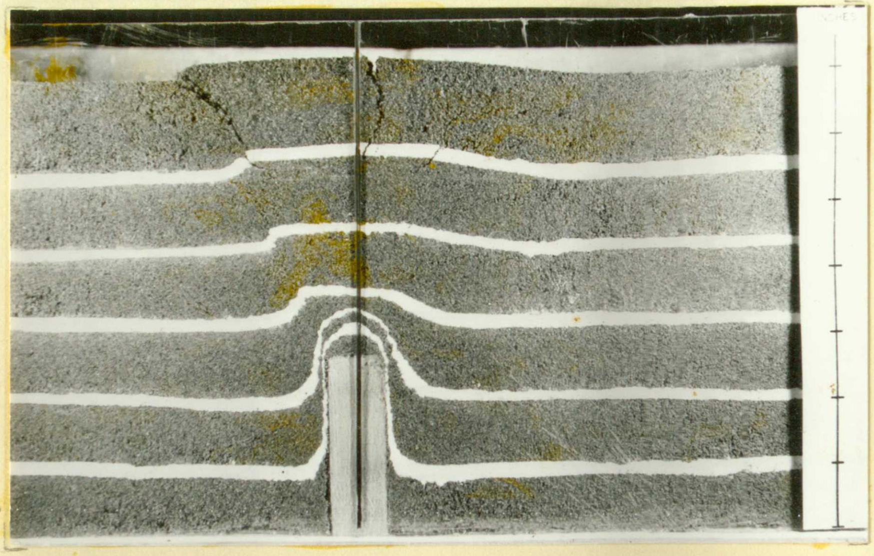
For the sedimentary strata, dry, subangular, medium-grained sand was used. Thin layers of dry plaster of Paris were used alternately with the sand for marker beds within the section. In the initial experiments, dry sand was used. This was found to be unsatisfactory for use in this model. Upon insertion of the plunger the dry sand shifted so rapidly that it was difficult to observe what deformation was taking place and structures would not persist long enough to photograph. This was solved by using damp sand; the addition of water to the sand increased the cohesion of the sand grains and increased the strength of the sand layer. Thus with the insertion of the plunger, any deformation produced was clearly shown and the experiments could be stopped at any stage for photographic recording of results.

The angle of insertion of the plunger was marked on the glass as a guide. Small deviations from the angle are common and are due to the difficulty of starting the plunger into the model in exact alignment with the line. The plunger was forced through the model by hand. It was noted that the faster the plunger was pushed into the model the more intense was the fracturing produced, and that very slow movement of the plunger deformed the beds to a high degree with very little fracturing. The same rate of penetration was maintained as nearly as possible throughout the experiments in order to provide uniform results for comparison.

The experiments were at first carried out at 15° intervals of inclination of the plunger. When the angle of the plunger seemed to be nearing that which would produce features such as those on South dome, the interval was decreased to 5°.

Photographic recording of the experiments was normally made at one-inch intervals of penetration. If significant structures developed, however, photographs were made regardless of penetration.

Only those experiments which the writer feels best illustrate the conditions involved will be presented here. Many intermediate experiments were carried out but are not



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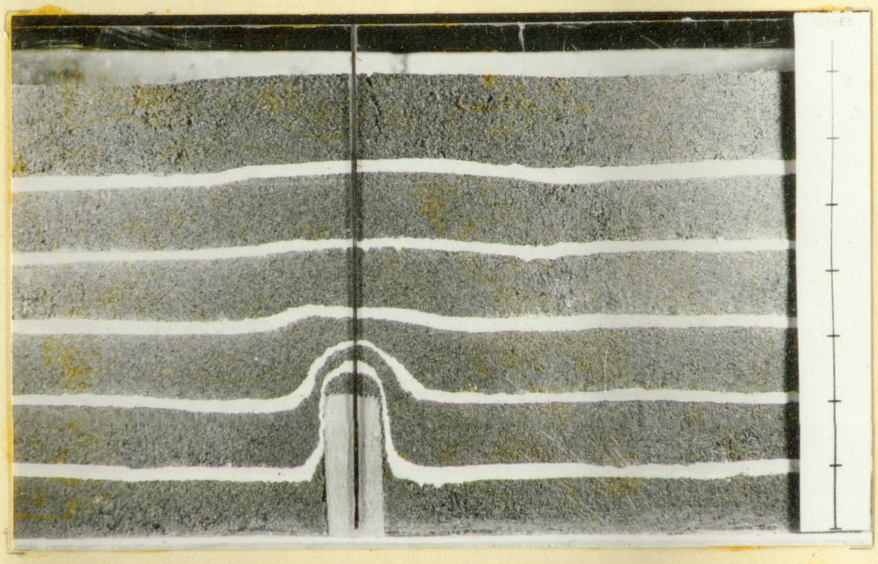

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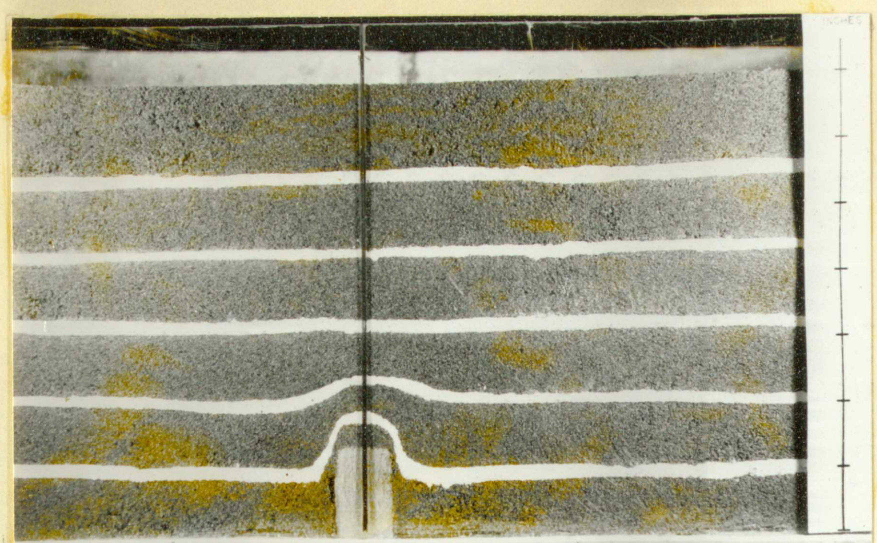
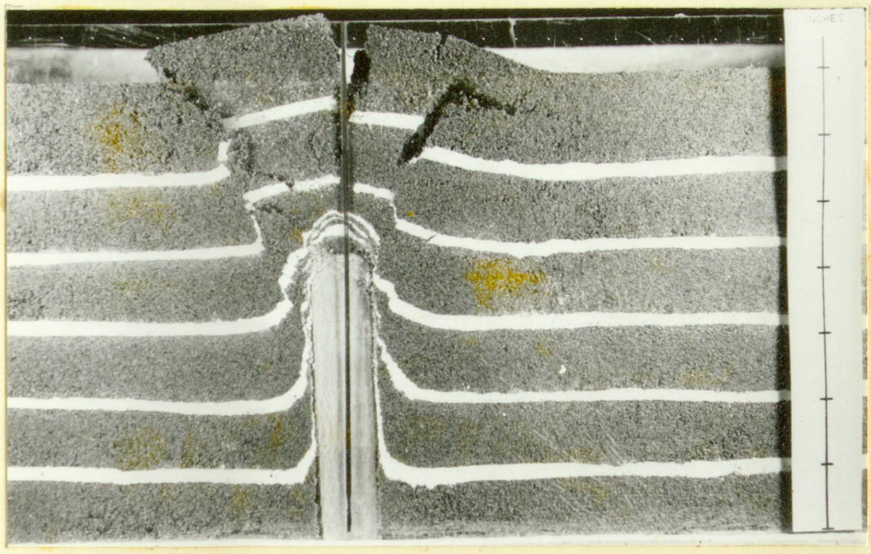


A

Plate 4. Model experiment 1. Plunger is vertical showing successive movements (A-F) of 1, 2, 3, $3\frac{1}{2}$, 4, and $4\frac{1}{2}$ inches.



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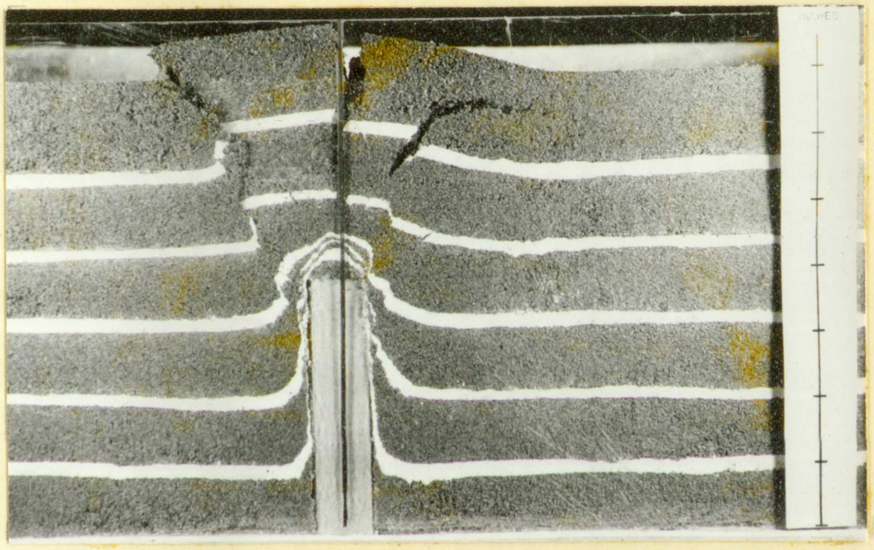

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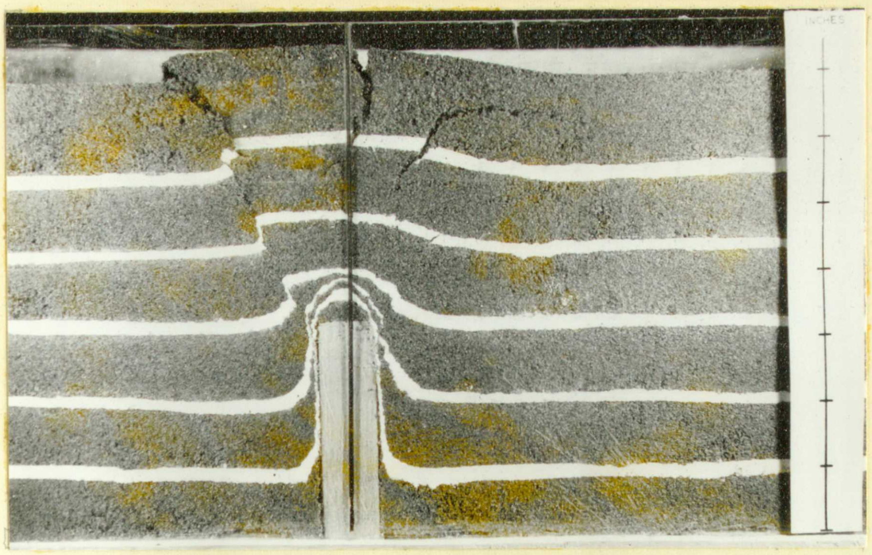


D

Plate 4. (continued)

used because no new significant features were formed.

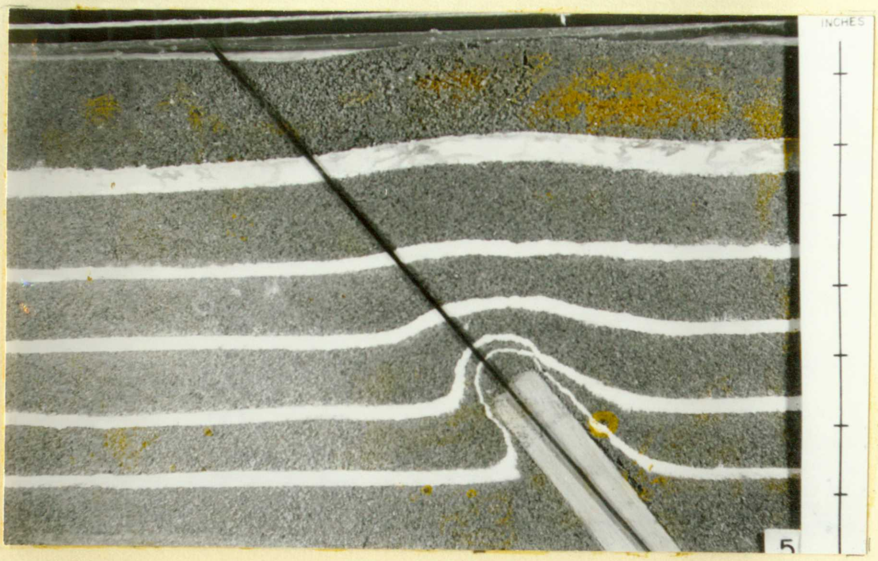
Experiment No. 1: Experiment No. 1 was performed with the plunger in a vertical position. The results of the experiment are shown on Plate 4. After a movement of one inch of the plunger into the sand, (4A), the lower plaster layer has been rather sharply bent but no fracturing has resulted. No observable distortion has taken place at the surface of the model. After the plunger has penetrated two inches into the sand, (4B), a slight doming of the surface is evident and a small tension crack has opened directly above the plunger. Actual fracturing of the marker beds does not occur until the plunger has traveled two and one-half inches into the sand, (4C).

It is interesting to note the asymmetric deformation of the beds due to a very slight deviation of the plunger from the vertical. The development of fractures in the marker beds has begun with the top bed. This is undoubtedly due to a lessening of the confining pressure created by the load. A reverse fault can be seen beginning to form at the surface. This fault continues to develop as the plunger is forced nearer to the surface of model, (4D, 4E, 4F). During the progress of the experiment it is noted that the fractures and reverse faults do not extend continuously

used because no new significant fractures were formed.

Experiment 15. It Experiment No. 1 was performed with the plunger in a vertical position. The results of the experiment are shown on Plate 4. After a movement of one inch of the plunger into the sand, (41), the lower plaster layer has been rather sharply bent but no fracturing has resulted. No observable distortion has taken place at the surface of the model. After the plunger has penetrated two inches into the sand, (42), a slight doming of the surface is evident and a small tension crack has opened directly above the plunger. Normal faulting of the marker beds does not occur until the plunger has traveled two and one-half inches into the sand, (43).

It is interesting to note the asymmetric deformation of the beds due to a very slight deflection of the plunger from the vertical. The development of fractures in the marker beds has begun with the top bed. This is probably due to a lessening of the confining pressure created by the load. A reverse fault can be seen beginning to form at the surface. This fault appears to develop as the plunger is forced nearer to the surface of model, (44, 46, 47). During the progress of the experiment it is noted that the fractures ~~as~~ faults do not extend continuously



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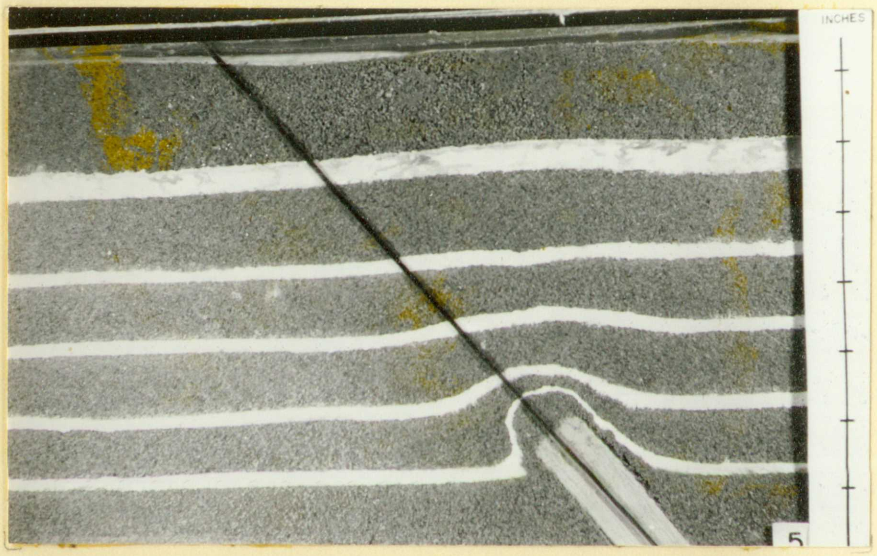

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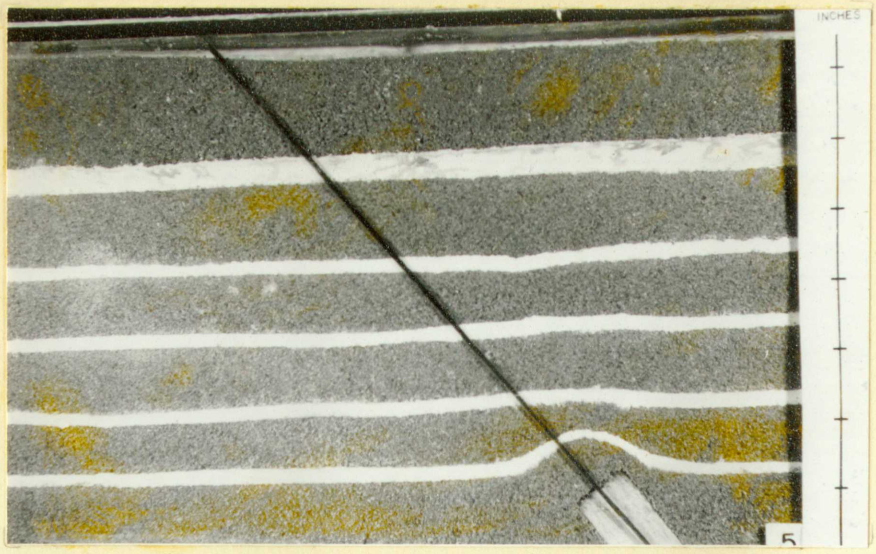
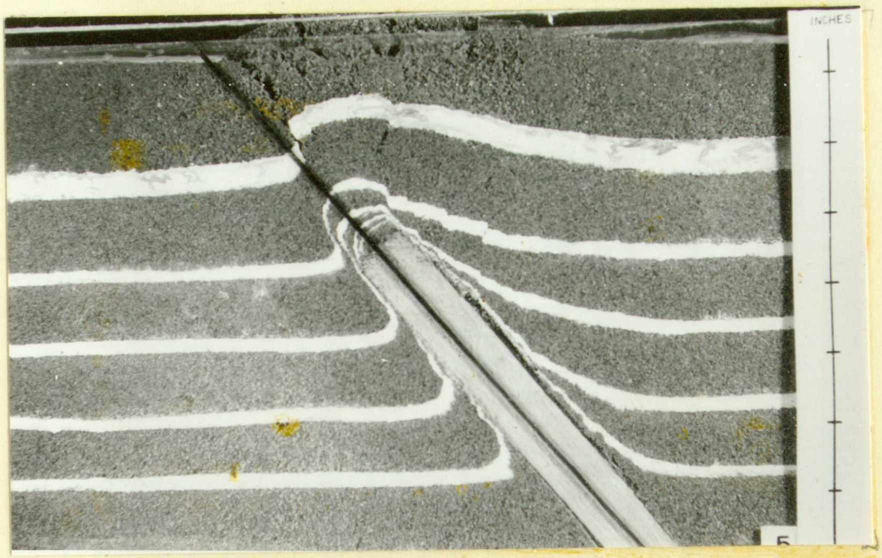


A

Plate 5. Model experiment 5. Plunger inclined at 45° showing successive movements (A-F) of 1, 2, 3, 4, 5, and 6 inches.



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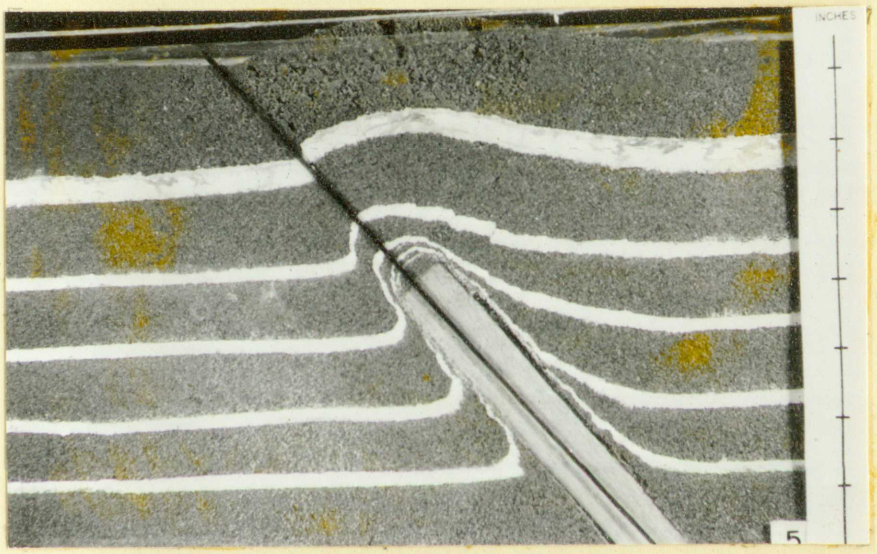

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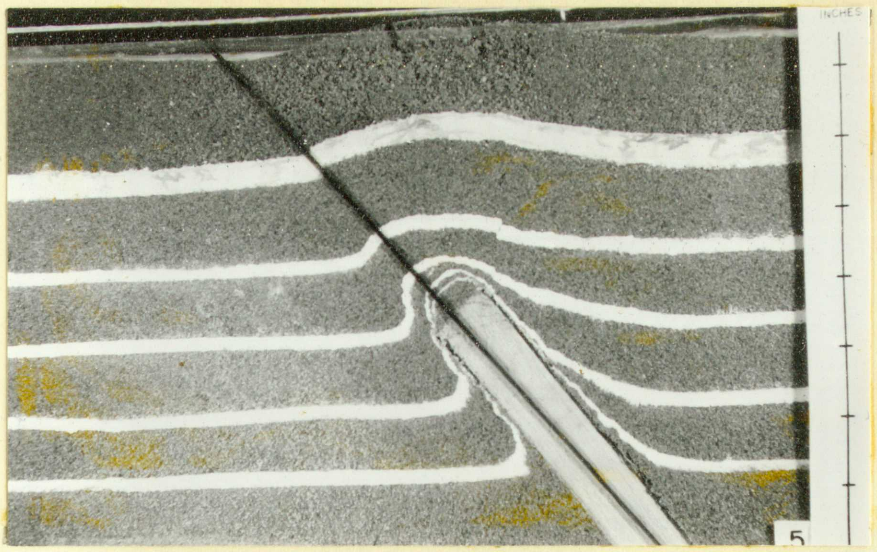
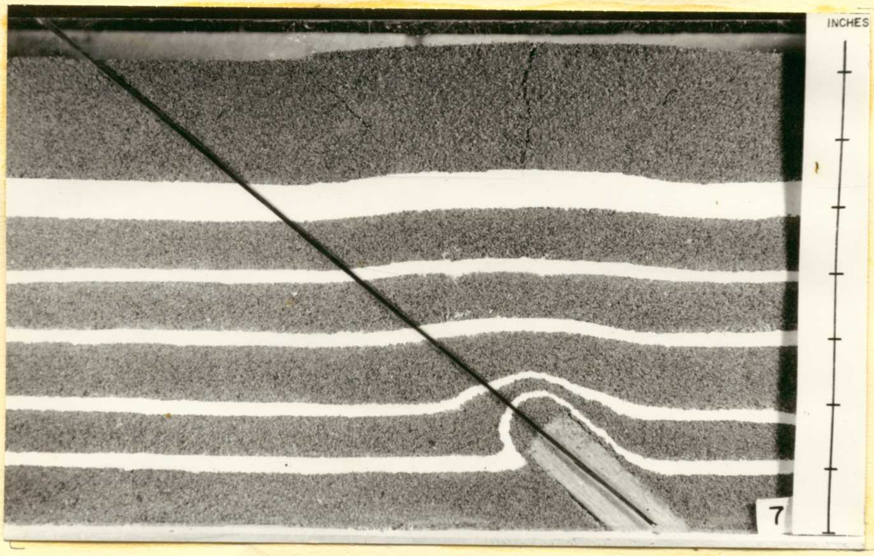


D

Plate 5. (continued)

from one bed to the next. The faults and fractures cut only one bed and then die out before reaching the one above. Thus the faults developed are not in a single plane from top to bottom but form a zone of many faults in an echelon pattern. It is interesting to note also the large open fault directly over the plunger (4E, 4F) which is normal at the surface and reverse at depth due to a curving of the fault plane.

Experiment No. 5: Experiment No. 5 was conducted with the model box loaded with alternate layers of sand and plaster of Paris as before. In this experiment the plunger was inserted at an angle of 45°. The results are shown in Plate 5. As the plunger is forced upward the beds are very symmetrically deformed at first (5A). Then as the plunger penetrates farther, one flank of the fold is steepened and finally becomes overturned (5B, 5C). No fracturing occurs until the plunger has penetrated almost half the thickness of the strata in the model. A feature of note in this experiment is the migration of the zone of maximum deformation at the surface. This zone moves across the model always maintaining a position that is almost vertical above the end of the plunger.



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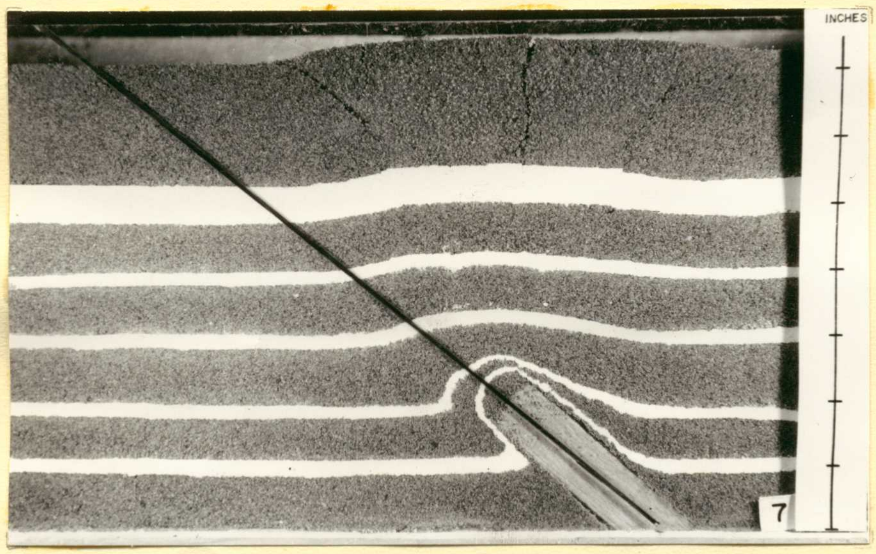

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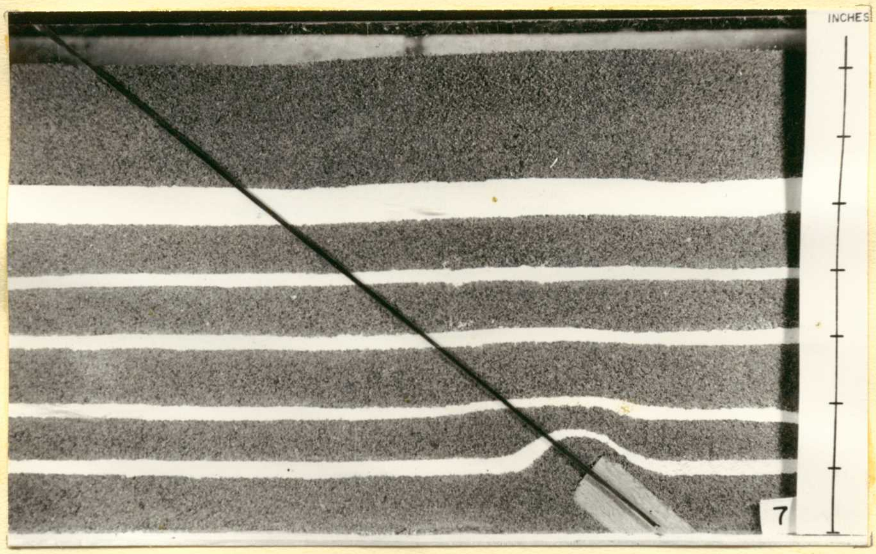
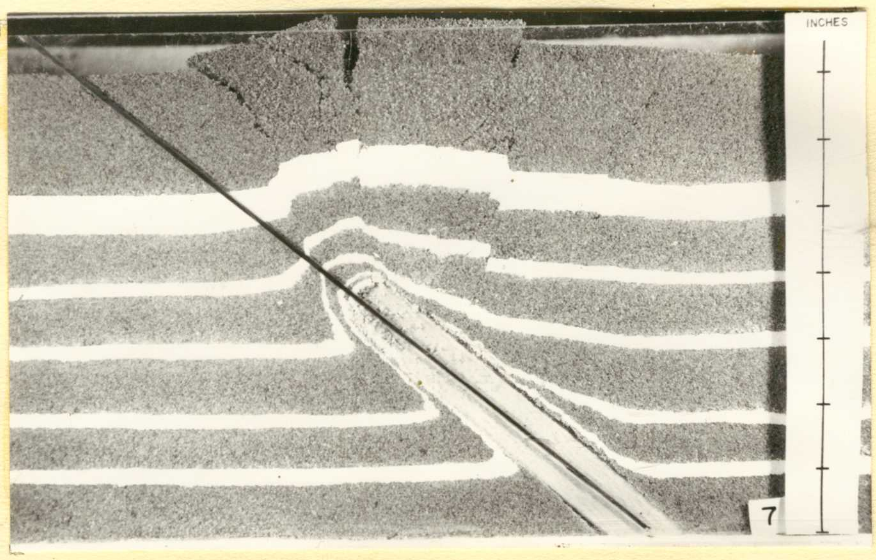


A

Plate 6. Model experiment 7. Plunger inclined at 40° showing successive movements (A-F) of 1, 2, 3, 4, 5, and 6 inches.



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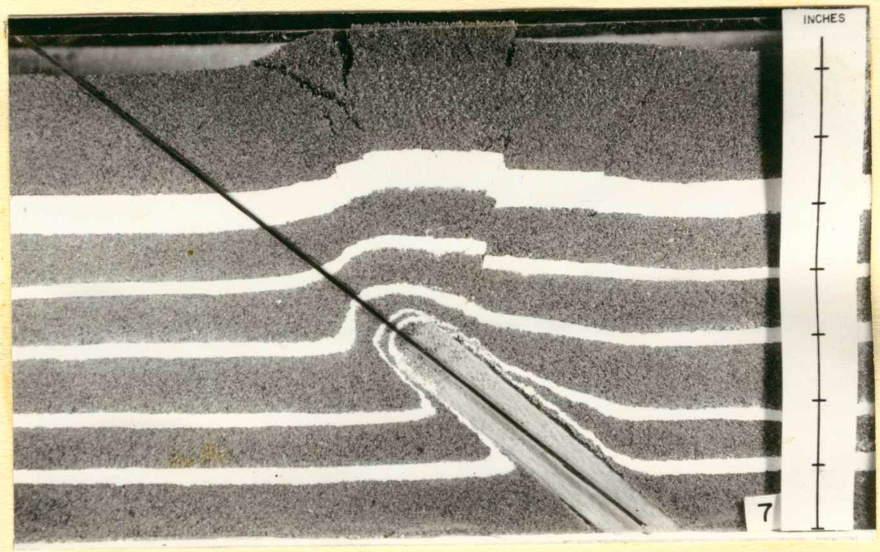

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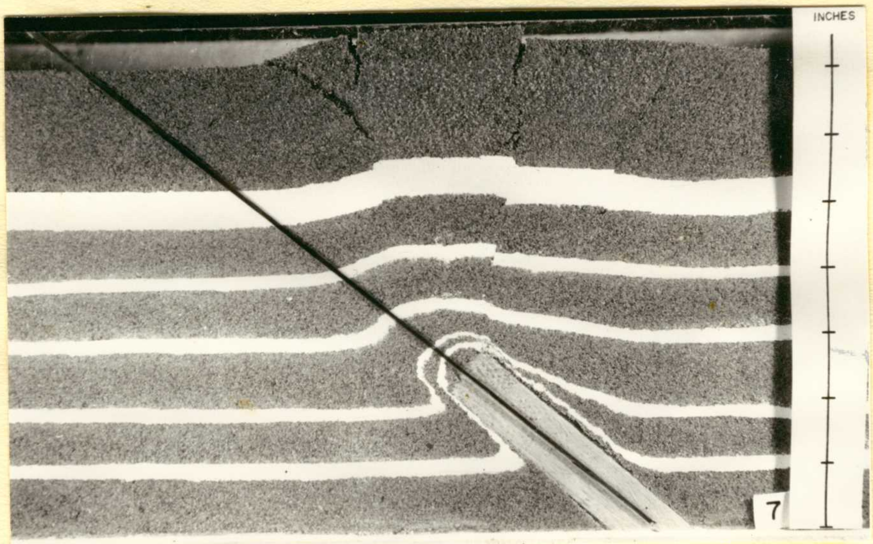


D

Plate 6. (continued)

Experiment No. 7: Experiment No. 7 was conducted with the plunger at an angle of 40° from horizontal as shown on Plate 6. In this experiment the deformation is very similar to that in Experiment No. 5. The main difference is the development of a steeper limb of the fold in the direction of penetration of the plunger. The development of this limb is shown very clearly in the center marker bed (6D, 6E). Another feature of this experiment is the development of fractures with much less penetration of the plunger than before.

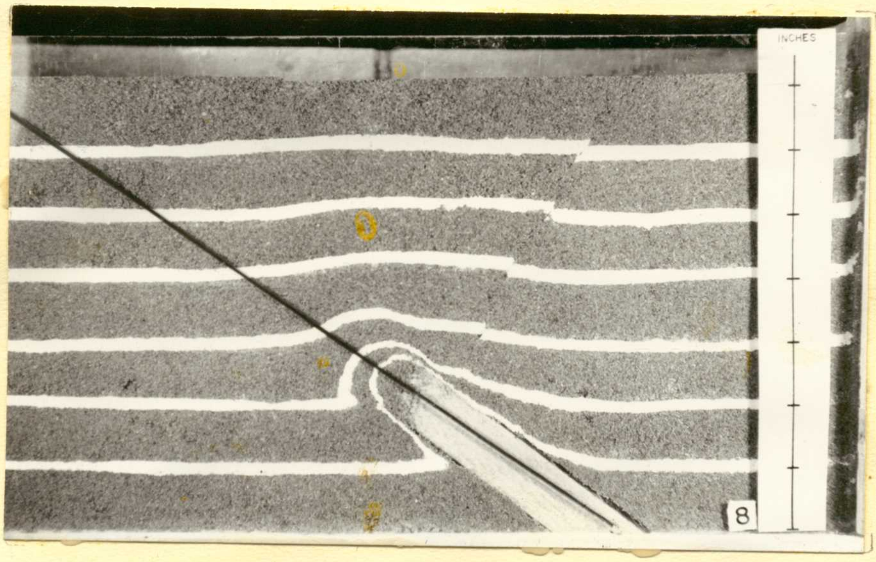
Experiment No. 8: Experiment No. 8 was made with the plunger at 35° from horizontal as shown in Plate 7. It is unique in the development of a single reverse fault very early. This fault begins to develop at 90° to the direction of force with a penetration of only two inches by the plunger (7B). It continues to develop throughout the experiment and is the only major fracture series formed. Very little deformation of the surface occurs in this experiment. This is probably due to model box being too short for the very low angle of penetration, thus the end of the model box prevents the strata from being displaced outward ahead of the plunger. Very little fracturing developed in the experiment and folding was very sharp.

Comparison of Experiments: A comparison of the model experiments is shown on Plates 8, 9, and 10. From these it

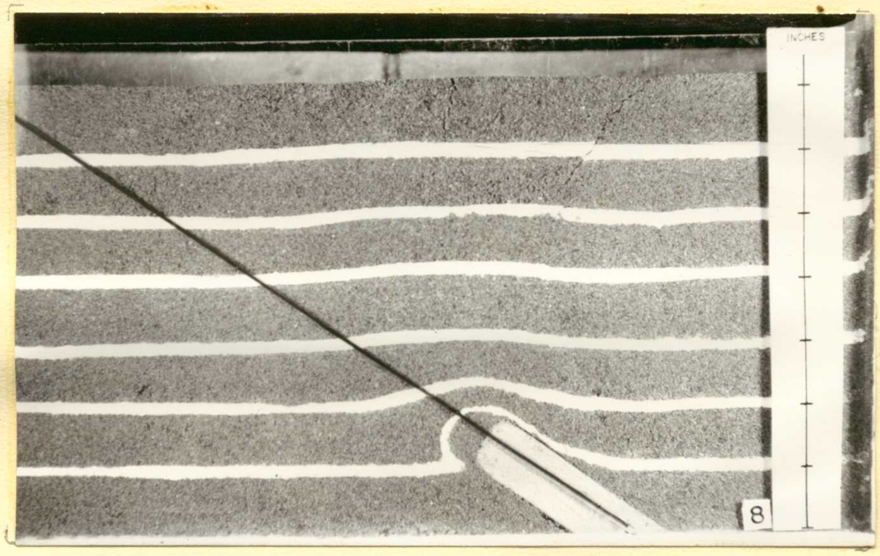
Experiment No. 7: Experiment No. 7 was conducted with the plunger at an angle of 40° from horizontal as shown on Plate 6. In this experiment the deformation is very similar to that in Experiment No. 6. The main difference is the development of a stronger limb of the fold in the direction of movement of the plunger. The development of this limb is shown very clearly in the outer marker bed (CD, DE). Another feature of this experiment is the development of fractures with movement concentrated in the plunger than before.

Experiment No. 8: Experiment No. 8 was made with the plunger at 35° from horizontal as shown in Plate 7. It is unique in the development of a single reverse fault very early. This fault begins to develop at 90° to the direction of force with a penetration of only two inches by the plunger (7B). It continues to develop throughout the experiment and is the only major fracture to be formed. Very little deformation of the layers occurred in this experiment. This is probably due to a small horizontal component of the very low angle of penetration, the component of the horizontal prevents the thrust from being transferred outward ahead of the plunger. Very little fracturing developed in this experiment and folding was very minor.

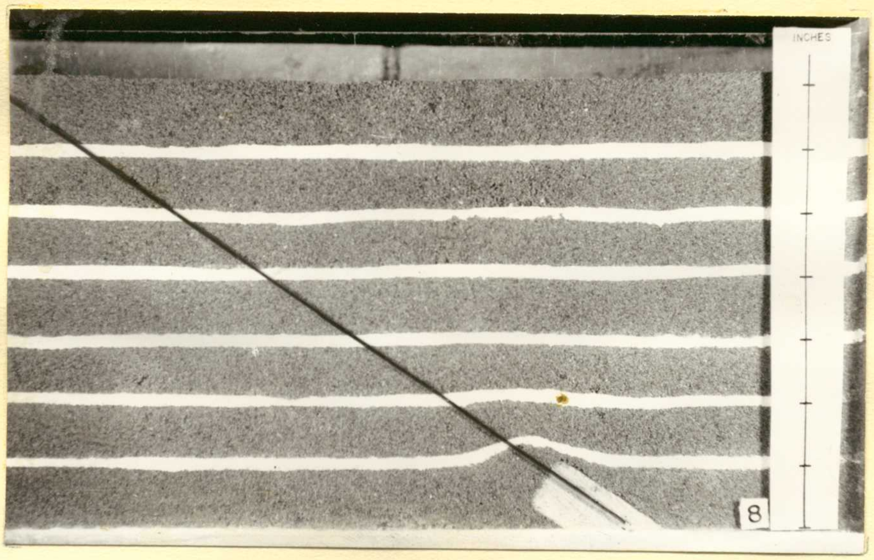
Comparison of Experiments: The comparison of the model experiments is shown on Plates 8, 9, and 10. ...



C

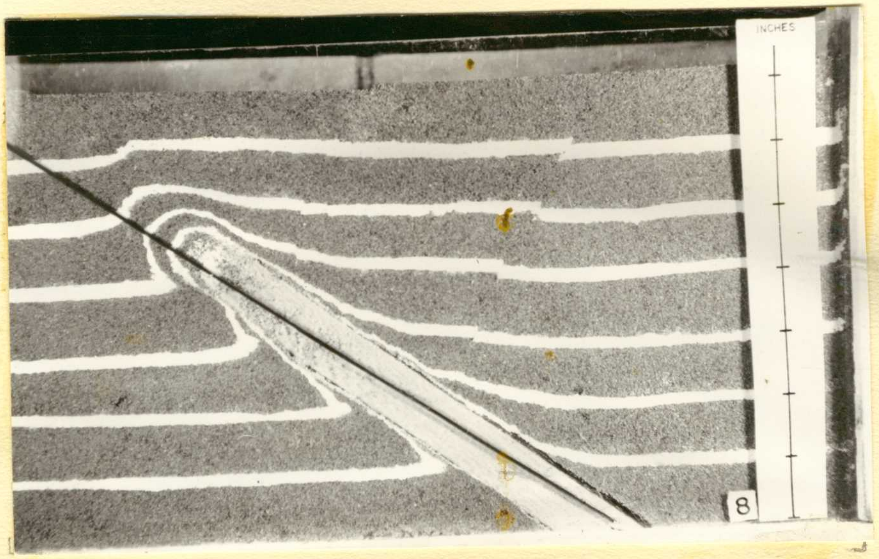


B



A

Plate 7. Model experiment 8. Plunger inclined at 35° showing successive movements (A-F) of 1, 2, 3, 4, 5, and 6 inches.



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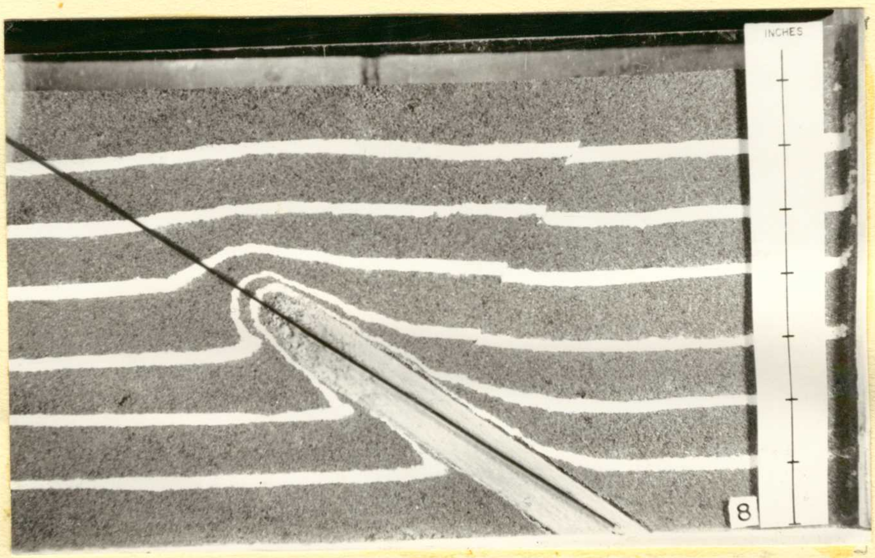
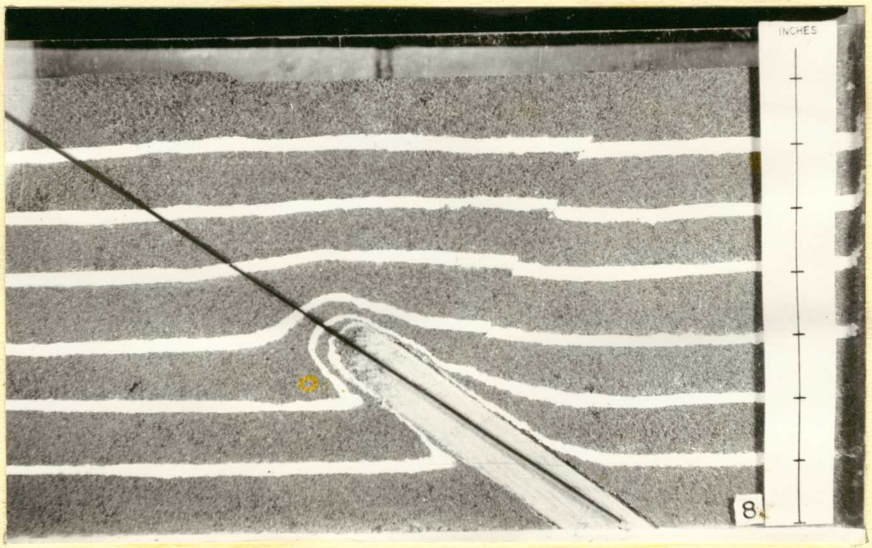


E



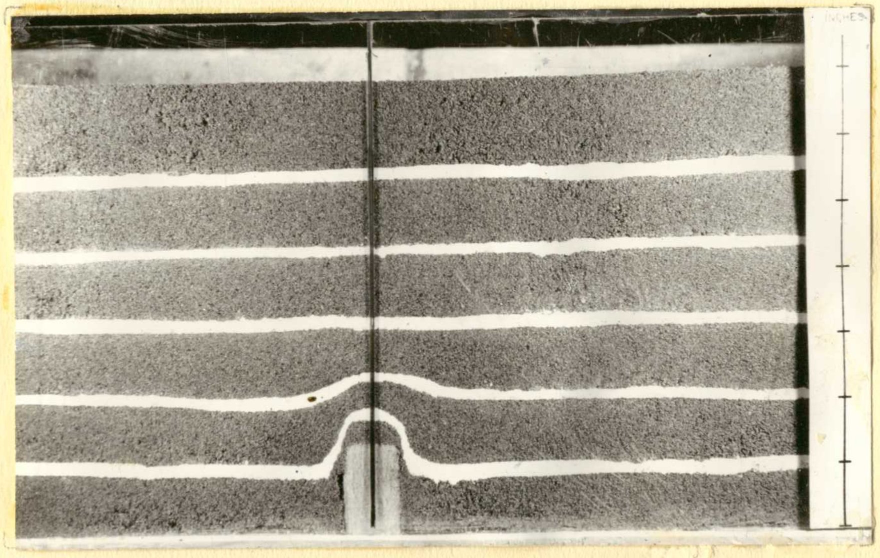
D

Plate 7. (continued)

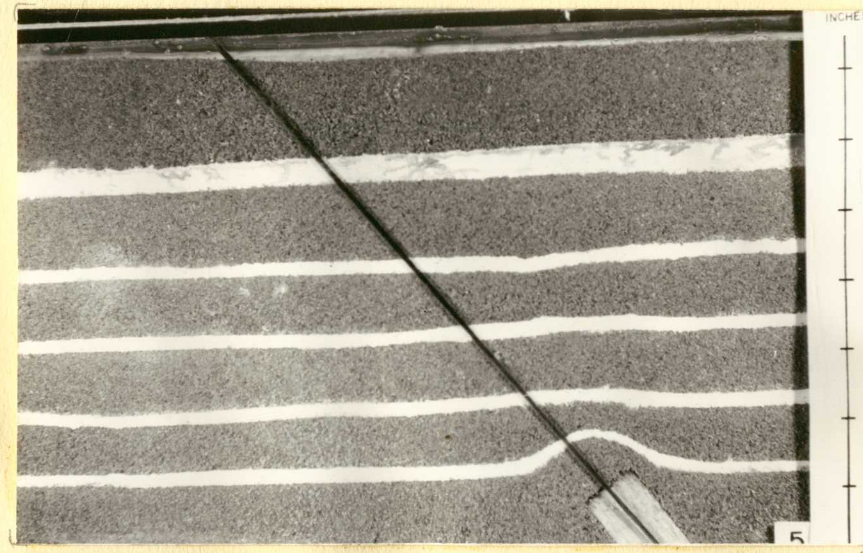
is evident that there is very little difference in the basic features. As shown on Plate 8, there is no difference in the deformation produced by a one-inch penetration of the plunger into the sand. All the folds produced are essentially the same and no fracturing has taken place.

As shown in Plate 9 the plunger has penetrated the sand three inches. The amount of folding produced is very similar, however, as the angle of penetration decreases, so does the symmetry of the fold decrease. The amount of fracturing and faulting developed is in direct relationship to the nearness of the plunger to the surface. Less fracturing is evident in the experiments with the plunger inclined then that with the plunger vertical because of the greater thickness of strata remaining to be penetrated. This has the effect of increasing the effective load over the plunger in an experiment where the plunger is inclined with relation to an experiment with the plunger vertical providing the depth of sand in the model box is the same in each case.

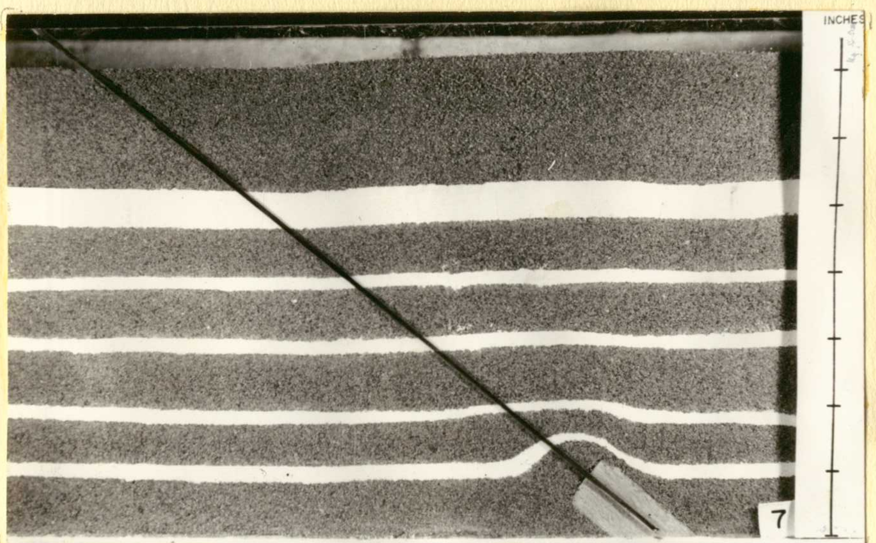
The comparison shown in Plate 10 illustrates the deformation of beds produced by various angles of penetration very clearly. As the angle progresses from vertical toward horizontal, one limb of the fold becomes increasingly steep and finally is sharply overturned.



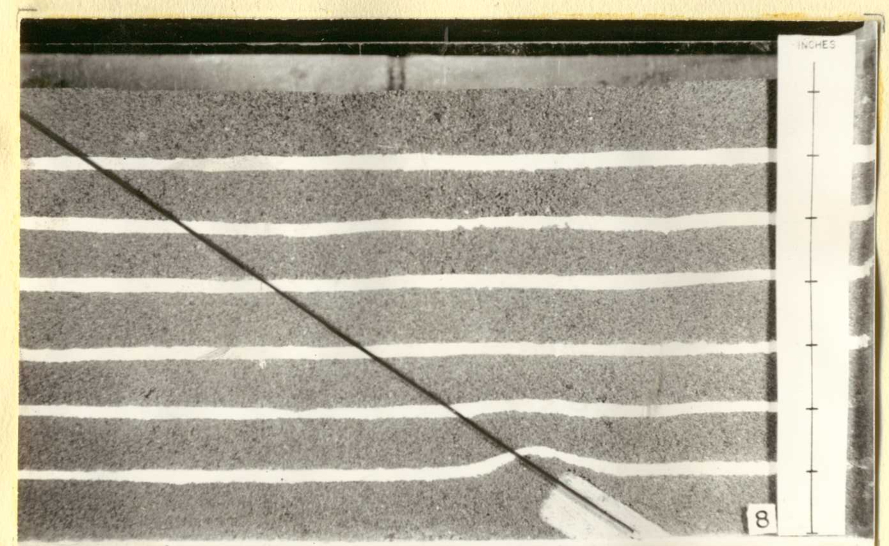
A



B

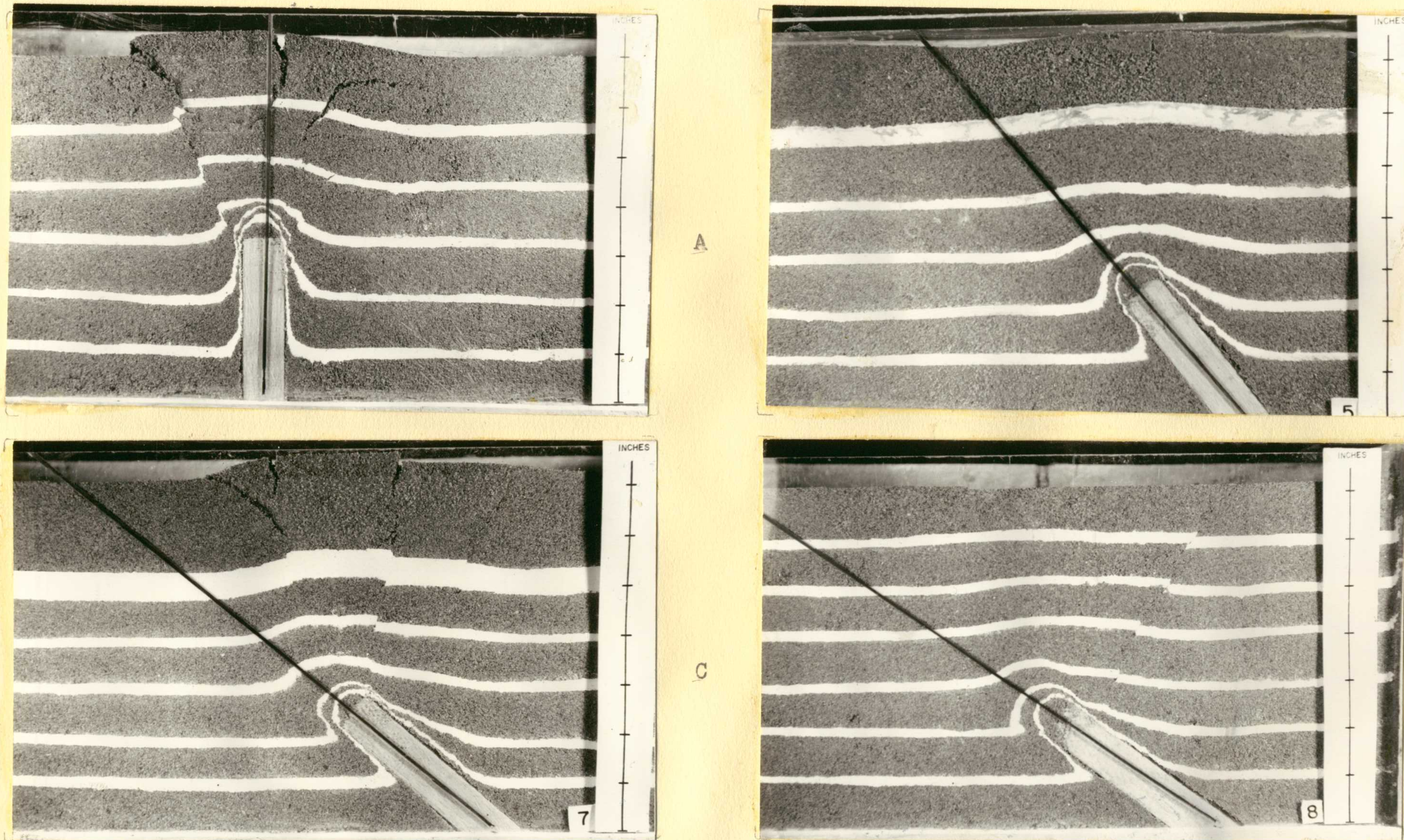


C



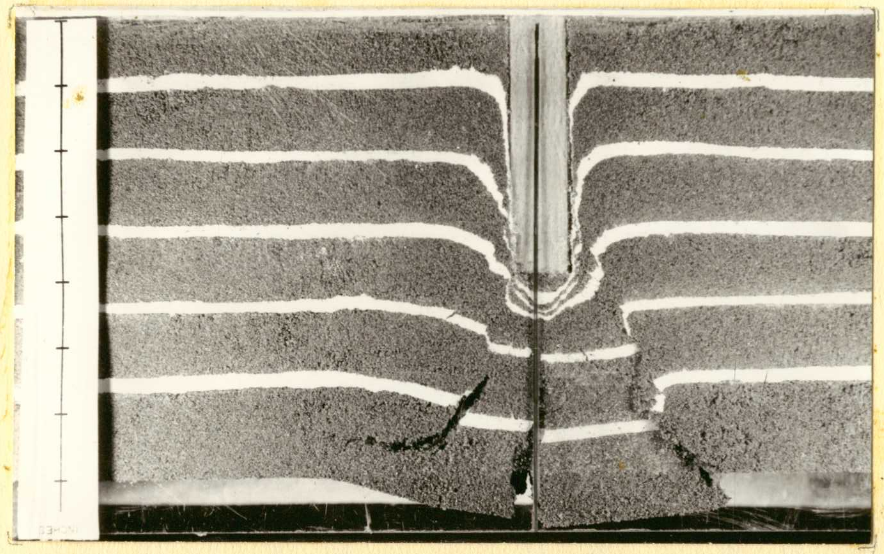
D

Plate 8. Comparison of model experiments at 1-inch penetration.
A, 90°; B, 45°; C, 40°; D, 35°.

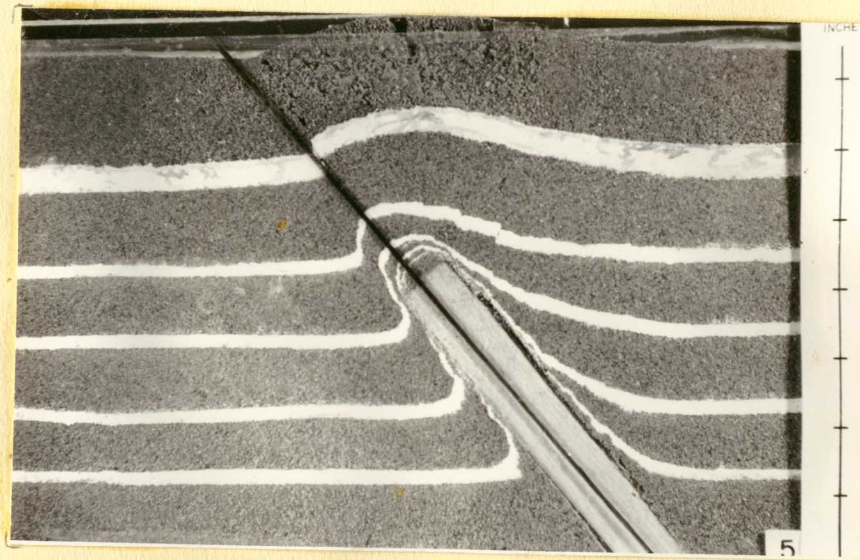


A B C D

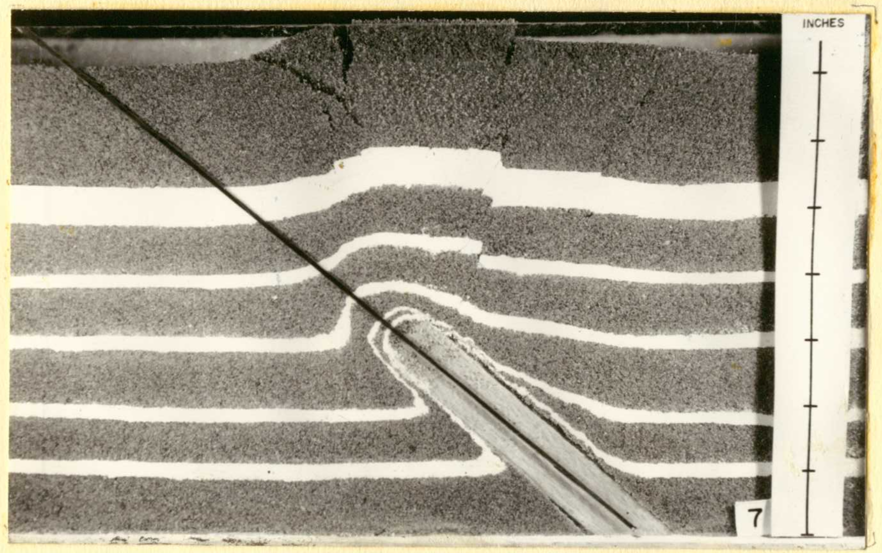
Plate 9. Comparison of model experiments at 3-inch penetration.
A, 90°; B, 45°; C, 40°; D, 35°.



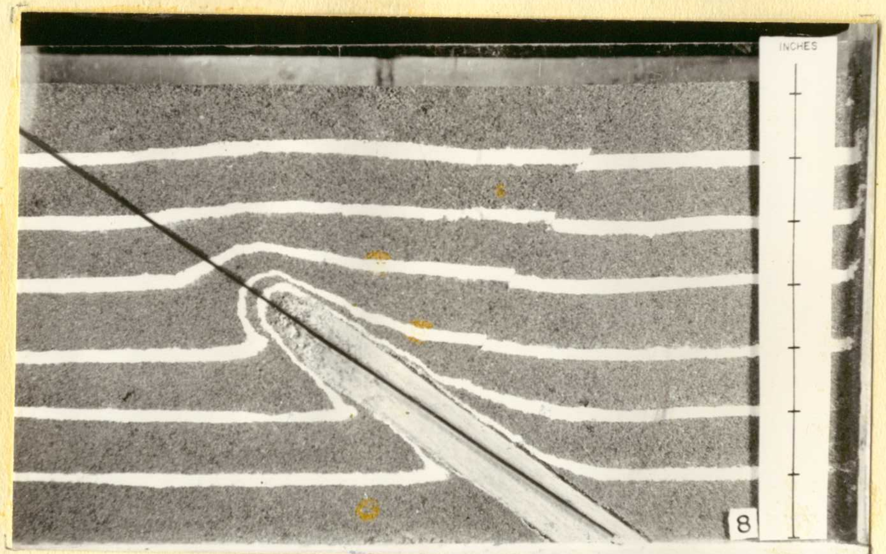
A



B



C



D

Plate 10. Comparison of model experiments at 4-inch penetration. A, 90°; B, 45°; C, 40°; D, 35°.

Relationship of Model Experiments to South Dome.— The structures developed during some of the model experiments show remarkable resemblance to those found on South dome. In some of the experiments, particularly 5 and 7, folds are produced at various stages that duplicate almost exactly the attitude of the beds on the dome.

One aspect developed in the model experiments is not found in connection with South dome. In the models the only type of faulting produced is reverse faults and no reverse faults were found in the field investigation. The only faults found on South dome are normal faults. It is the opinion of the writer that the absence of reverse faulting on South dome as compared with the model experiments is a result of the scale-ratio strength of the sand layers in the model being much greater than the earth's crust. It is believed that very little faulting at all developed as a result of the intrusive formation of the dome and that the deformation was more plastic than was found to be the case in the models. The normal faults found on the northwest flank of South dome may have been opened as tension cracks and with the cooling and accompanying contraction of the intrusive mass, these fissures were planes of weakness and developed into normal faults with a settling of the dome.

The nearly circular outcrop of the beds around the dome is the result of more rapid erosion of the highly fractured crest and steep limbs. The more gentle limbs of the dome stand considerably higher topographically than do the steep limbs.

From the evidence thus presented it is the opinion of the writer that South dome is the result of an intrusive igneous body which was forced upward at an angle of about 40° to 45°. Also, the igneous mass is at relatively shallow depth below the surface as is indicated by the model experiments (Fig. 5). On the basis of the evidence produced it is understandable how a well could be drilled on or near the crest of the dome and not encounter an igneous body.

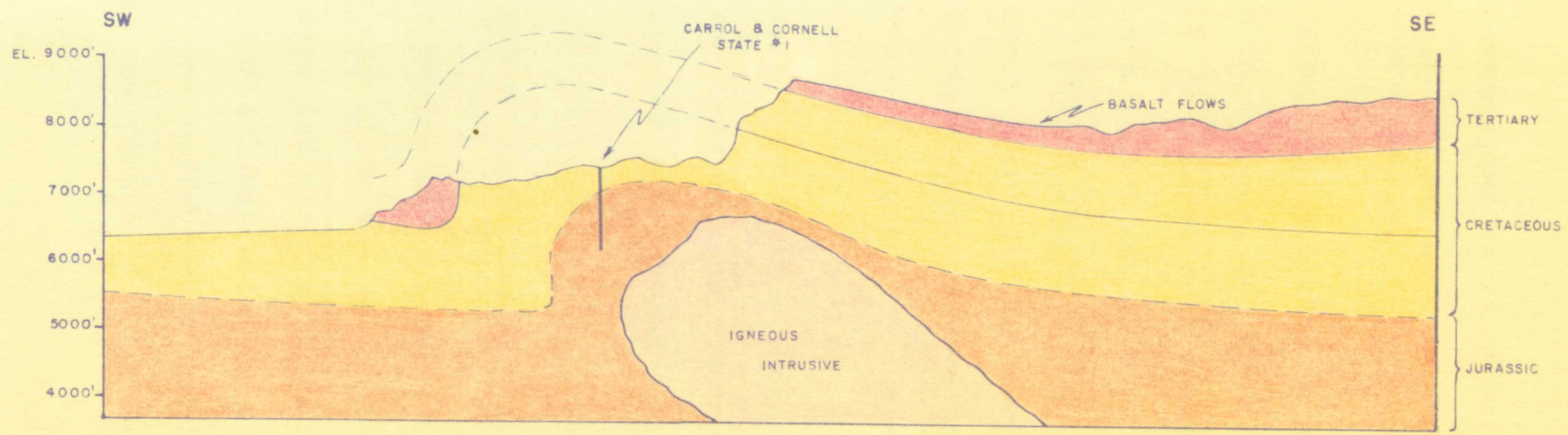


Figure 5. Assumed position of igneous intrusive beneath South dome.

MINERAL RESOURCES

General Statement

The Rinconada Canyon area has been extensively explored, though without much success, for mineral deposits of economic value. A wildcat well was drilled in the southern part of the area but was plugged and abandoned after no shows of oil or gas were found. In the northern part of the area, along the sides of Guadalupe Canyon, strip-mining operations have been carried out for coal; however, the grade is low and it is difficult to mine. Hence, it is not an economic deposit at this time. At the present time there is considerable exploration for uranium, and numerous mining claims were staked in the area during the preparation of this report.

Pumice

Extensive deposits of pumice are located along the sides of Guadalupe Canyon and along the west side of Rinconada Canyon. These deposits are Tertiary in age and are the result of the initial explosive phase in the eruption of Mount Taylor. The tuff-breccia was deposited on erosion surfaces around the flanks of Mount Taylor

where it truncates the gently northwesterly dipping Cretaceous sediments. The breccia reaches a maximum thickness of 388 feet at the head of Guadalupe Canyon and is made up of alternating massive and stratified zones.

The pumice has not been exploited in this particular area. Mining of the pumice deposits here would be both difficult and costly owing to their location high in the canyon walls and beneath a cap of basalt 75 to 150 feet thick.

Just a few miles to the west at East Grants Ridge both pumice and perlite are mined extensively. This material is trucked to the United States Gypsum Company's mill at Grants where it is crushed and graded for use in acoustic plaster and as polishing abrasives (Johnston, 1953).

Coal

The only coal beds in the Rinconada Canyon area are found in the lower part of the Gibson coal member of the Mesaverde formation. Farther to the west the Dilco coal member is an important coal-producing horizon; however, in this area it contains no commercial coal beds, being composed mostly of sandstone and sandy carbonaceous shale with occasional stringers of coal a few inches thick.

Coal beds in the Gibson are confined to the lower 300 feet; however, black carbonaceous shale can be found throughout the entire member. The coal beds are usually very thin but laterally several thin beds may merge into one with a thickness of as much as five feet. Beds of this thickness do not extend for any great distance and usually grade laterally into thin coal beds, shale, or sandstone. The coal is of subbituminous rank and usually contains much sand.

Some exploratory stripping has been done along the east side of Guadalupe Canyon. Terraces have been cut into the canyon wall at several levels to expose the coal beds. In some of the thicker beds further exploration was carried out by horizontal auger drilling.

Some coal has been hauled away but tonnages and values are unknown and the operation has been abandoned.

Oil and Gas

There are two domal structures in the Rinconada Canyon area, each with approximately 1000 feet of structural relief. Hunt (1936, p. 80) states that:

> "The domes along the south side of Mount Taylor provide satisfactory closure to serve as petroleum reservoirs, but any prospecting of them should not be undertaken without considering the general lack of success of drilling the larger domes in the region and the difficult access to the crests of the domes."

Coal beds in [illegible] contained [illegible] lower 300 feet, however, [illegible] throughout the entire area. The coal beds generally vary in thickness [illegible] and [illegible] of [illegible] five feet. Beds of this thickness do not [illegible] for any [illegible] distance but usually grade laterally into thin coal beds, shale, or sandstone. The coal [illegible] usually contain much ash.

Some exploratory [illegible] along the outcrop of [illegible] have been cut into the canyon wall [illegible] the coal [illegible] exploration was [illegible] details.

[illegible]

values [illegible].

Oil and Gas

There are two [illegible] structures in the [illegible] Canyon area, which were [illegible] 1930 [illegible] structural [illegible] (1930, p. [illegible]) further [illegible]

"[illegible] the [illegible] of [illegible] should [illegible] in the [illegible] of the [illegible]."

In 1945 on NW SW NE Sec. 36, T.11 N., R.8 W. on South Dome, Carroll and Cornell drilled the State #1 to a depth of 1167 feet with no shows of oil or gas. This hole was collared in the Mancos shale just off the crest of the dome and bottomed in the Morrison formation of Jurassic age. Further data on this hole is not available since a log was not filed with the State Department of Conservation nor the State Bureau of Mines and Mineral Resources. It is the view of the writer from evidence presented in this report that this structure was formed too late to be an effective trap for oil or gas and any formation or regional migration of hydrocarbons had probably taken place long before its formation.

The formation of North dome was contemporaneous with the folding of the McCarty syncline within which it lies. It seems apparent that this structure is better suited for the accumulation of oil or gas. However, the nearness of this dome to the center of volcanic activity must be taken into consideration and any accumulation of oil or gas may subsequently have been driven off due to the heat.

Uranium

As was stated previously, currently there is uranium exploration activity in the Rinconada Canyon area. Many lode mining claims have been staked and filed in this

area in recent months. The exploration has thus far been confined to surface work; in the Mesaverde formation no exploratory drilling has been done to date. Because of the area's close proximity to the famous Jackpile mine of the Anaconda Company and the easily recognized structures which may act as a control for ore deposition, it is expected that this area would receive considerable attention.

The Morrison formation of Jurassic age which is the principal uranium ore-producing horizon is not exposed in the Rinconada Canyon area, the nearest outcrops being several miles to the south. A small mineralized zone was found on North dome at the base of the Dilco coal member of the Mesaverde formation. It consisted of schroeckingerite coatings on the sand grains along small fractures and bedding planes. The mineralization is confined to a thin sandstone stringer in the lower part of the Dilco shale. The sand is poorly cemented and contains numerous carbon fragments. The sandstone does not exceed one foot in thickness and the mineralization may be traced for about seven feet along the outcrop. The occurrence of uranium mineralization in a structurally deformed area such as this indicates the possibility of finding a commercial ore body in more favorable strata, such as the Morrison formation, at depth. Exploration of this formation by drilling would be very costly however, with minimum

area in recent months. The exploration program has been confined to surface work in the [illegible] exploratory drilling [illegible] the area's close [illegible] the Anaconda Company and [illegible] which may [illegible] expected that [illegible]

The [illegible] of [illegible] principal [illegible] in the Anaconda [illegible] several miles [illegible] found on North [illegible] of the [illegible] Formation. [illegible] coatings on the [illegible] bedding planes. [illegible] sandstone [illegible] The [illegible] fragments. The sandstone [illegible] thickness and [illegible] seven feet [illegible] mineralization [illegible] this indicates [illegible] ore body [illegible] Formation, [illegible] drilling would [illegible]

drilling depth on the order of 1600 to 2000 feet. Exploratory drilling to these depths is not economically feasible at this time.

Conclusions

The mineral resources of the Rinconada Canyon area have thus far not been of particular economic importance. However, extensive deposits of pumice and coal are found in the area and the possibility of commercial deposits of oil and uranium at depth cannot be completely discounted. In future years this area may contribute appreciably to the economy of the State.

CONCLUSIONS

From this investigation of the Rinconada Canyon area the following conclusions are apparent:

1. North dome is contemporaneous with the McCarty syncline and is a result of the same forces that caused the folding of the syncline.
2. North dome is older than the Mount Taylor eruptions as is evidenced by the volcanic rocks which rest on an erosion surface cut across the folded strata.
3. South dome is younger than the Tertiary basalt flows which were involved in its formation.
4. South dome is the result of an igneous intrusive mass rising not vertically but inclined at an

angle of 40° to 45° as is indidccated by model experiments.

5. The mineral resources of this aarea may be of great value but require furtherrr exploration and development.

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Figure 6

1 map in pocket