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GEOLOGY OF THE CABALLO MOUNTAINS

By Caswell Silver
Consulting Geologist

The geology of the Caballo Mountains is more fully described under the same title in publication No. 4 of the University of New Mexico Publications in Geology by Kelley and Silver (1952). This account is largely a resume of parts of the more detailed information contained therein.

STRATIGRAPHY

The Caballo Mountains contain rocks ranging in age from Precambrian to Recent, with rocks of every age represented but Triassic and Jurassic and probably Lower Cretaceous. Granitic rocks with lesser amounts of gneiss and schist comprise the Precambrian and make up 10 per cent of the total outcrop area. The total sedimentary section has a maximum thickness of approximately 17,000 feet as shown in the table (Fig. 1).

A brief description of each formation in the Caballo Mountains from the bottom up follows.

BLISS FORMATION: CAMBRO-ORDIVICIAN (Stratigraphic correlation chart in pocket.)

The over-all appearance of the Bliss formation is that of a dark-brown to black band beneath the light grays of the overlying El Paso. It generally forms a slope continuous with the underlying Precambrian. Thickness is between 110-160 feet. Except for a few basal medium-to-thick-bedded ledges of coarse grained sandstone and oolitic hematite, the Bliss is thin-bedded and commonly liminated within the thin beds. The lowermost part of the Bliss formation in the Caballo area, up to 15 or 20 feet above the base, is generally dominated by coarsely textured beds consisting of conglomerate, conglomeratic sandstone, coarse and often feldspathic sandstone and oolitic hematite. The oolitic hematite beds occur about 10 to 15 feet above the base of the formation in thicknesses of five to six feet. Above the lowermost coarse clastic part, the Bliss consists of alternating thin beds and laminations of gray, commonly glauconitic limestone, dolomite, ferruginous, quartzose, fine-grained sandstone and siltstone, glauconite and non-oolitic hematite.

In the Caballos a brachiopod, *Westonia stoneana,* is especially evident and common but other brachiopods as well as graptolites and trilobites have been found. The Bliss crosses systemic boundaries and is Upper Cambrian in its lower part and Lower Ordovician in its upper part. Because it wedges over areas of relief it may be possible to find some localities where it is Ordovician only.

Age	Stratigraphic units		Thickness (feet)
Quaternary	Valley fill and pediment gravel		0— 500
Tertiary	Santa Fe formation		2,000±
	Thurman formation		2,000—2,500
	Palm Park formation		1,000+
	McRae formation		3,000+
Cretaceous	Mesaverde formation		2,500+
	Mancos shale		400— 500
	Dakota sandstone		125— 250
Permian	Manzano group: San Andres formation		700—1,000
	Manzano group: Yeso formation		200—1,200
	Manzano group: Abo formation		500— 900
Pennsylvanian	Magdalena group: Bar B formation		335+
	Magdalena group: Nakaye formation		420+
	Magdalena group: Red House formation		360+
Mississippian	Lake Valley formation	Nunn member	0— 13
		Alamogordo member	0— 36
Devonian	Percha formation		0— 105
Silurian	Fusselman dolomite		0— 50
Ordovician	Montoya group: Cutter formation		0— 162
	Montoya group: Aleman formation		0— 170
	Montoya group: Upham dolomite		20— 80
	Montoya group: Cable Canyon sandstone		0— 35
	El Paso group: Bat Cave formation		216— 305
	El Paso group: Sierrite limestone		127— 167
Cambrian	Bliss formation		110— 160
Precambrian	Granite, gneiss, and schist		
	Total (maximum) thickness of sedimentary rocks:		17,248

Figure 1. Stratigraphic table of the Caballo Mountains area.

EL PASO GROUP: LOWER ORDOVICIAN

The El Paso limestone of the Franklin Mountains has been expanded in the Caballo Mountains to a group divided into the Sierrite limestone and the Bat Cave formation by Kelley and Silver (1952).

SIERRITE LIMESTONE. The Sierrite limestone is separated from the Bliss formation by (1) contrasting mineralogy and lithology and (2) contrasting beddedness. (Stratgraphic correlation chart in pocket.)

Oolitic hematite and sandstone are not present in the Sierrite, and glauconite is only sparsely present in the lowermost beds. The Sierrite limestone crops out as a massive light-brown ledge above the dark-colored Bliss. Its thickness in the Caballo Mountains ranges from 120 to 170 feet. It is conformable with the confining formations and is 120 feet thick at Molinas Canyon, 167 feet at Cable Canyon, 140 feet near Palomas Gap, and 150 feet in the Mud Springs Mountains. It is characteristically thin-to-medium-bedded and weathers in thin slabs. The thin

beds and laminations result in a distinctive banded appearance. Laminations consist of alternating layers of limestone and chert with the latter generally the thinner. The chert laminations are brown-weathering and in number per foot of thickness of rock range from 5 to 60. The irregularity of the chert laminations further results in embossed reticulations on the bedding planes.

On fresh surfaces the Sierrite limestone is medium-gray to dark-gray with a slight brownish cast. The limestone is almost entirely calcite at the type locality. At the Molinas Canyon section in the southern end of the range a few thin lentils of brick-red shale are present about 35 feet above the base.

Complete distinctive fossils are rare in the Sierrite limestone of the Caballo Mountains and this is generally true for southern New Mexico. A few poorly preserved gastropods of several genera were collected from the top few feet of the formation at the type locality. The following forms have been identified by S. A. Northrop: *Lytospira?* sp., *Ophileta* sp., *Orospira* sp., *Orospira?* sp., and *Ozarkispira* sp. *A* few endoceroid siphuncles were also collected nearby. All the diagnostic fossil collections which have served to establish early Ordovician or Canadian age of the El Paso group have come from beds which are lithologic and stratigraphic equivalents of the overlying Bat Cave formation.

The Sierrite limestone appears to have been deposited in quiet shallow seas which covered a shelf area of the Sonoran trough located across New Mexico. The deposits appear to have accumulated slowly by rythmic chemical precipitation of calcium carbonate and silica in earliest Ordovican time.

BAT CAVE FORMATION. The Bat Cave formation comprises the upper and major part of the El Paso group in the Caballo Mountains. The type locality is the north side of Cable Canyon, sec. 10, T. 16 S., R. 4 W., and the formation is named from the Bat Cave whose opening is a prominent landscape mark on the sheer cliff in the upper part of the unit a few hundred yards northwest of the type section. The formation rests conformably on the underlying Sierrite limestone and is overlain with marked erosional unconformity by the Cable Canyon sandstone of the Montoya group.

The Bat Cave formation crops out boldly along most of the west escarpment of the Caballo Mountains. It ranges from 216 feet at Molinas Canyon to 305 feet at Mud Springs Mountains. The variation is chiefly due to pre-Montoya erosion.

The lower part of the formation is light gray in general appearance and is generally slope forming. The upper part is somewhat darker and banded in general appearance and is generally cliff forming. The highest and sheerest cliffs of Timber Mountain are those formed by the upper part of the Bat Cave formation.

The stratigraphy of the Bat Cave formation is complicated by lateral variations in lithology and beddedness resulting from reeflike or biohermal masses which are piled upward across the normal section in some places for several tens of feet or occasionally for hundreds of feet. At the type section the formation is composed of two principal divisions of about equal thickness.

The upper unit of the Bat Cave formation is strikingly exposed in the cliffs adjacent to the Bat Cave on the north side of Cable Canyon. Its highly banded outcrop is typical and consists of medium-to-thick-bedded alternating dark-gray and medium-gray limestone, dolomitic limestone, and some dolomite. Most of the beds are very fine grained and dense, and when broken yield a faint fetid odor. Beds of calcarenite and calcirudite are commonly intercalated with the normal autochthonous limestone. Cherty beds or intervals are occasionally present. The chert is weathered light brown to dark brown and occurs as nodules and bands. It is medium gray on fresh exposure. An interval of banded chert occurs near the top in the Cable Canyon section.

One of the most outstanding features of the Bat Cave formation is the presence of large masses of collapse breccia in the upper part of the formation. These masses extend downward from the upper contact for as much as 200 feet and extend laterally at least several hundred feet in places. In other places the breccia occurs as rib-shaped masses beneath the overlying Cable Canyon sandstone, but in general the breccia appears to have developed in masses that vary considerably in shape and dimension.

Fragments of the collapse breccia are dominantly boulders, but they range from coarse-grained calcarenite to blocks several tens of feet across. Although the fragments are dominantly carbonate rock, locally chert and sandstone fragments are scattered in the mass. In some places the breccia is loose and highly vugular, but in other places it is well cemented.

The upper surface of the Bat Cave formation at its contact with the Cable Canyon sandstone appears in many places to be quite smooth and regular. At other places it is distinctly undulating or ragged. In detail, small channels or depressions may be seen at the contact. In some places the Cable Canyon sandstone ledge appears to have been obliterated by caving into the underlying Bat Cave collapse structures,

but because of poor exposures this aspect has not been closely observed. In most places the Cable Canyon sandstone rests undisturbed on the underlying breccia.

Most of the recorded fossils collected from the El Paso group in southern New Mexico have come from rocks which are the stratigraphic equivalents of the Bat Cave formation. Except for the algae represented by the stromatolites, the formation is sparingly fossiliferous in the Caballo Mountains, at least to the unspecialized eye. The greatest number of forms was noted in the type section at Cable Canyon and at Mud Springs Mountains. In order of abundance they include gastropods, trilobite and cephalopod fragments, and sponges, and the few specimens present are usually firmly embedded in rock.

MONTOYA GROUP: MIDDLE AND UPPER ORDOVICIAN

The Montoyo group consists from the bottom up of the Cable Canyon sandstone, Upham dolomite, Aleman formation, and Cutter formation named by Kelley and Silver (1952) from the Caballo Mountains.

CABLE CANYON SANDSTONE. The Cable Canyon sandstone is one of the most useful stratigraphic markers in the lower Paleozoic section. It is a coarse granulitic sandstone that appears as a dark band above the light colored cliffs of the Bat Cave formation.

With rare exceptions it is a ledge or cliff in all exposures. Its lower contact with the Bat Cave formation has been discussed. The upper contact may be either a sharp bedding-plane separation of sandstone and limestone or an irregular gradation upward without apparent division by bedding planes from sandstone to limestone. It is everywhere one single bed, 17 to 35 feet in thickness. No cross-bedding was noted in the Caballo Mountains.

The sandstone is medium gray on fresh exposure and contains grains of white, gray, pale rose, smoky, and blue-gray quartz, gray chert, and dolomite. No other clastic minerals were noted. The cement is responsible for much of the over-all color of the rock on fresh exposure. Surfaces are characteristically rough with protruding grains and weathered to a mottled gray and brown, which is the over-all color.

The Cable Canyon sandstone appears to occur both as an originally deposited bed with lithologically sharp upper and lower contacts and as a reworked unit incorporated into a bed of dolomite. Evidence for its reworked character is the sandstone-breccia blocks lying within the solution sinks developed in the upper part of the Bat Cave formation, which are overlain by either a sandstone bed of similar lithology or by clastic limestone. There is much evidence to indicate that locally the Cable Canyon sandstone has been reworked and redeposited in some areas as a clastic basal bed of the Upham dolomite.

UPHAM DOLOMITE. Resting conformably on the Cable Canyon sandstone in the Caballo Mountains is the massive-bedded, medium-gray-to brownish-gray-weathering Upham dolomite. The distribution of the Upham dolomite in the Caballo Mountains is generally the same as that of the Cable Canyon sandstone, with a few additional areas of exposure east of Truth or Consequences, in the North Red Hills, Nakaye Mountain, and Derry Hills. In many exposures it is a cliff or ledge for its full thickness of 20 to 80 feet.

The dolomite is microcrystalline to coarsely crystalline and medium gray to dark gray on fresh exposure. Locally there is no sharp separation from the underlying Cable Canyon sandstone, and choosing the contact becomes an arbitrary matter of distinguishing sandstone from sandy dolomite in a completely gradational lithology with no discernible bedding plane. Included detrital quartz grains identical to those of the underlying Cable Canyon sandstone occur as scattered grains, thin lentils, and irregular vertical streaks, the last possibly representing the filling of animal borings. Sand as a constituent decreases upward in quantity and the upper part generally contains no sand. Primary chert, although occasionally present, is not abundant and the absence of chert generally contrasts strongly with the overlying Aleman formation. Where chert is present it occurs as scattered nodules of irregular shape which are as much as 12 inches in greatest dimension, or as thin bands similar in appearance to the chert found in the overlying Aleman formation. In several localities where the Upham dolomite is medium to coarse grained, the formation shows excellent intergranular porosity. This coarse texture contrasts with the overlying Aleman and Cutter formations. Fossils are scarce.

ALEMAN FORMATION. The most distinctive formation of the Montoya group, the lithology of which has often been said to characterize the Montoya, is the Aleman formation. It consists of alternations of chert and dolomite beds which form a strikingly banded outcrop. The Aleman formation has a general distribution in the Caballo Mountains similar to that of the other formations of the Montoya group. Its outcrop is either in a slope or a cliff. The chert is usually differentially weathered to the dolomite and although the over-all color is medium gray to dark gray brown, in detail the chert weathers white,

brown, and black and the dolomite, light gray to medium gray. The chert occurs as irregular bands one to three inches thick alternating with one to six inch bands of dolomite. The Aleman cherty beds range from 120 to 170 feet in thickness in the Caballo Mountains. (Stratigraphic chart in pocket). The banded chert of the Aleman formation, although distinctive to the practiced eye, cannot always be used as the sole means of identification for the formation in isolated outcrops, as locally beds of the Bat Cave, Fusselman, and Nakaye formations approach it in appearance.

The dolomite is medium to dark gray, brownish gray, or pinkish gray on fresh exposure, and microcrystalline to granular. Secondary dolomite and limestone crystals in seams and vugs both show a pink color. The chert is mottled light and dark gray on fresh exposure and is commonly a replacement of fossils. The rock is irregularly fossiliferous but fossils when present occur usually in great abundance as one to two inch streaks and lenses of broken shells, much like stringers of beach-rubble zones. The fossil shells of the Aleman are invariably replaced by chert and are beautifully preserved. The weathered-out specimens are common in many outcrops. Many of the complete brachiopods are filled with crystalline quartz.

The most characteristic fossil of the Aleman chert is a brachiopod, *Zygospira recurvirostris*, which has been found at many places in the Caballo Mountains at approximately the same position in the lower part of the formation. Many of the Zygospiras are attached to the rock in weathered-out clusters in the positions in which they may have been living when buried.

Fossils determined by S. A. Northrop are:

Cornulites cf. *C. currugatus* or *C. flexuosus*,
Rafinesquina sp. (abundant fragments),
Rynchotrema sp.,
Strophomena sp. (abundant fragments),
Zygospira recurvirostris (abundant).

Lee (1908, p. 182-184) reported collecting in the Caballo Mountains a much more varied assemblage of forms from "the base, near the middle, and at the top" of what is undoubtedly the combined Montoya and Fusselman beds. Ulrich (Lee, 1908) included these in one general fauna for purposes of identification. As no distinction was made between Montoya and Fusselman, the lists will not be repeated here. Darton (1928, p. 13) listed 36 species from the upper beds of the Montoya for New Mexico which were identified by Ulrich and Kirk. He also listed six principal species collected from the basal beds.

CUTTER FORMATION. Overlying the Aleman formation in the Caballo Mountains with apparent conformity is a sequence of light-gray-weathering, generally unfossiliferous limestone and dolomite beds which are designated as the Cutter formation. This formation usually crops out as a steep slope beneath the Fusselman. The Cutter has the same general distribution as the other formations of the Montoya group except where it has been locally removed in part or entirely by pre-Pennsylvanian erosion in the southeast end of Nakaye Mountain. South of Palomas Gap in the central part of the Caballo Mountains, the formation ranges in thickness from about 50 to 115 feet in a distance of two miles, and then increases to about 130 feet at Granite Wash. (Stratigraphic chart in pocket). These rather abrupt changes in thickness may be attributed to pre-Fusselman truncation. The dolomitic limestone is light gray to brownish gray on fresh surfaces. The dolomite is medium gray to dark gray. Both weather light gray or light tan. Only a few of the dolomite beds are finely crystalline. The limestone is generally microgranular to sublithographic.

FUSSELMAN DOLOMITE: SILURIAN

The Fusselman dolomite overlies the Montoya group in most places in the Caballo Mountains, but in some localities Percha or Magdalena strata rest directly on the Montoya and the Fusselman is absent. The Fusselman is a dark-gray to brownish-gray cherty dolomite which often forms a cliff or ledge beneath the Percha or lower Magdalena beds. It is less than 50 feet thick and throughout much of its extent is less than 20 feet.

PERCHA FORMATION: DEVONIAN

In most places the Percha formation rests upon the Fusselman, in other places it rests upon dolomite of the Montoya group. It is most commonly overlain by beds of the Magdalena group, but in the southern end of the mountains the Lake Valley formation intervenes. The general topographic expression is that of a slope above a bench. The formation is everywhere soft, thin-bedded, and ranges in thickness from a thin edge to 105 feet. It consists predominantly of gray-weathering calcareous claystone, olive-drab-weathering shale, and rusty-weathering fine-grained sandstone and siltstone. The claystone is light gray to medium gray on fresh exposures, somewhat gritty, and contains limestone nodules ranging from pebble to boulder size. Thin limestone lentils and beds are irregularly distributed. The shale is fissile and breaks into shiny olive-green chips which form a distinctive float. Limonite concretions are common.

The Percha shale laps onto an irregular surface

in the Caballo Mountains so that its basal beds are not everywhere the same age. Likewise the top is irregularly truncated so that its highest beds also are not everywhere the same. In general a sandy unit 50 feet thick at the top of the Percha in Haystack Canyon, sec. 1, T. 18 S., R. 3 W., appears to be represented by only six feet at Timber Mountain and four feet at Derry. This unit appears to contain some of Stevenson's "Sly Gap" fauna (Stevenson, 1945). Whether this fauna is the ecological expression of the differing lithology in the Percha of the Caballo Mountains has not been determined. Exposures are generally poor and mantled with debris, and units have not been traced.

LAKE VALLEY FORMATION: MISSISSIPPIAN

The Lake Valley formation is only partly represented in the Caballo Mountains and such exposures as were positively identified were found South of T. 16 S. in R. 3 W. Only the Alamogordo and the Nunn members have so far been found as isolated patches between the basal beds of the Magdalena formation of Pennsylvanian age and the Percha formation of Devonian age.

The Alamogordo member is a massively bedded, dark-gray-weathering, ledge-forming limestone, 31 feet thick. Actually, it is one massive bed containing lense-shaped chert masses, four to six inches thick and two to three feet long, frequently alined in the same plane parallel to the bedding. These are so distributed as to appear to divide the limestone along bedding planes but, where well exposed, many of the lenses are not related to bedding and thus contribute to a distinctive outcrop appearance.

The limestone is light gray to medium gray on fresh exposure and finely crystalline. The chert lenses weather pink in many localities but are medium gray to white on fresh exposure. The chert lenses are much shattered and as a result weather back into hollows. Fossils are sparsely present and are altered to rusty, brown-weathering chert. They occur as scattered individuals and are generally imbedded firmly in the rock. The forms present, in order of their abundance, are: crinoid columnals, horn corals (two genera), brachiopods, and cephalopods (rare). Most common are crinoid columnals of several kinds, one of which has a sharp-pointed five-rayed axial canal. These usually weather out of the limestone and sparsely stud the surface of the rock.

The Nunn member of the Lake Valley formation is a thin-bedded, nodular light-gray-to pinkish-gray-weathering crinoidal limestone and shale unit as much as 30 feet thick. It rests unconformably on the Percha formation or on the Alamogordo member of the Lake Valley limestone. It is unconformably overlain by limestone of the Magdalena group. The rock where not stained is white to medium gray on fresh exposure. It is extremely fossiliferous and specimens weather out in great profusion. In order of abundance, the principal forms are: crinoids, corals, brachiopods, bryozoans, trilobites, and echinoids.

MAGDALENA GROUP: PENNSYLVANIAN.

The Pennsylvanian rocks of the Caballo Mountains, as elsewhere in New Mexico, can be divided, following Read and Wood (1947, p. 223), into "(1) A suite of transgressive sediments; (2) evenly and widely distributed marine sediments that were deposited during a period of maximum marine transgression; and (3) unevenly distributed and restricted alternating marine and continental sediments that represent a period of offlap or marine regression."

The threefold transgressive-to-regressive division of the Magdalena group as outlined by Read and Wood appears to be present in the Caballo Mountains, but its lithologic expression deviates somewhat from that in central New Mexico.

Except for the Cenozoic rocks, the Magdalena group has the greatest areal extent of any mapped unit in the Caballo Mountains. Furthermore, except for Flat Top and Red House Mountains, the Magdalena forms the crests of the main ridges of the mountains as well as those of Mud Springs Mountains and several smaller ridges in the area. On the whole, the group crops out with considerable prominence. It is gray or tan gray in general appearance. The ledginess of the Magadalena contrasts strongly with that of the lower Paleozoic formations. In the Ordovician rocks the limestone and dolomite beds are piled on each other through great thickness, whereas the limestone beds of the Magdalena are separated by extremely numerous shaly layers several feet or more in thickness so that the beddedness is markedly ledged in the outcrops. As a result, and because of the barrenness of the terrian, the Magdalena is readily separated from the older formations--at a distance as well as on air photos. Also, the Magdalena may be readily distinguished in most places from the San Andres limestone outcrops, which, although gray and banded, are more undulating than those of the Magdalena. In the numerous dip-slope or near dip-slope exposures of the Magdalena group a highly scalloped outcrop pattern is developed.

The only complete section of the Magdalena group measured was across South Ridge a few miles south of Palomas Gap. Except for a few tens of feet, the total thickness of the group is excellently exposed in the western escarpment of South Ridge, and from

the Rio Grande Valley to the west a good view of nearly the entire group may be had. The thickness attained in this section is about 1,120 feet. General observations and calculations made from cross sections indicate that the Magdalena varies in thickness considerably in the Caballo area. It is probably nowhere less than 1,000 feet thick and in the southern part of the area it may be as much as 1,700 feet thick.

The group was divided in the Caballo Mountains by Kelley and Silver for stratigraphic purposes into three formations which correspond to the broad suites of Read and Wood (1947). In ascending order these are the Red House, Nakaye, and Bar B formations.

The group, formation, and member units listed by Thompson (1942) from the Caballo Mountains were based on the succession of fusulines rather than on the principles and guiding procedures suggested by the American Commission on Stratigraphic Nomenclature and as a result they have been generally ignored. The usefulness of Thompson's work in New Mexico would be established by the relating of the faunal succession to mappable units.

RED HOUSE FORMATION. The Red House formation comprises about the lower third of the Magdalena group where measured at South Ridge. It is named from Red House Mountain in the southern part of the area where good exposures occur in several places. At the type section along South Ridge the Red House formation is 362 feet thick and rests on the Cutter formation of late Ordovician age. Elsewhere in the Caballo area it rests on the Upham dolomite, as in North Red Hills and near the Universal fluorspar mine where its base is only a few feet above the Cable Canyon sandstone. In many places in the southern part of the area the Red House rests on the Percha formation and locally in the southeastern part of Red House Mountain it rests on the Nunn member of the Lake Valley formation. However, insofar as local outcrops are concerned, there is a general parallelism between the Red House and the underlying strata, and only the broader relations indicate the true nature of the erosional surface upon which the formation was deposited. The maximum stratigraphic relief of the erosional unconformity at the base of the Magdalena is about 500 feet. The pre-Pennsylvanian topography was buried by the Magdalena deposits and the Red House formation varies in thickness because of depositional onlap in the Caballo Mountains.

The Red House formation consists dominantly of thin-bedded limestone and shale or claystone with limestone nodules and lenses. It is gray to dark gray and usually slope forming. Locally massive limestone beds that are commonly very cherty are present. A thin sandstone bed locally marks the base of the formation, and a coarse-grained and conglomeratic sandstone ledge is widely present in the northern part of the mountains near the middle of the section. Many of the limestone and shale beds of the formation are abundantly fossiliferous. Limestone conglomerate and calcarenite occur in many places in the lower part of the formation and these appear to have been derived from the Mississippian and older carbonate rocks.

NAKAYE FORMATION. In the Caballo Mountains the Nakaye formation is the most prominent part of the Magdalena group. However, it comprises but little more than the middle third of the group in the type section measured at South Ridge. The name is taken from Nakaye Mountain in the southwestern part of the area where the formation forms most of the ridge. At the type section the formation is 419 feet thick. However, it appears to thicken slightly southward or southeastward along the range.

The Nakaye formation rests conformably on the Red House formation. It consists dominantly of thick to massive ledges of limestone which often contain abundant bands, lenses, or nodules of chert. The limestone is medium gray to dark gray and very fine grained to fine grained in most places. Many of the beds weather to a light tan-brown and others weather light gray to medium gray. No sandstone occurs in the section and this affords a noticeable contrast with similar parts of the Magdalena in central New Mexico.

BAR B FORMATION. The Bar B formation comprises about the upper third of the Magdalena group and is 339 feet thick where measured at the type section on South Ridge. It appears to thicken slightly to the south and southeast.

The Bar B formation consists dominantly of thin-bedded limestone and shale in alternating thin intervals. It resembles the Red House formation and appears to have been laid down in a similar sedimentary environment. It differs from the Nakaye formation in the over-all change from dominant limestone to dominant shale. Whereas 80 percent of the Nakaye formation is limestone and the remainder shale, the ratio is nearly reversed in the Bar B formation. This change in lithology results in contrasting beddedness which serves to distinguish the two formations. Although the Bar B is a highly clastic formation, it remains fine grained and, as with the Nakaye formation, sandstone is absent except near the top. Both cherty and noncherty limestone are present. The

chert is commonly mottled and weathers to tan or yellowish brown. The formation contains numerous fossiliferous beds and bryozoans are especially abundant; this feature might be used to distinguish the unit from the Red House formation.

The uppermost beds of the Bar B are intercalated with reddish-brown siltstone, limestone conglomerate, and calcareous sandstone through an uneven stratigraphic interval of about 50 feet.

ABO FORMATION: PERMIAN (?)

The Permian (?) and Permian rocks of the Caballo Mountains consist of the Abo, Yeso, and San Andres formations, and their aggregate thickness is about 2,000 feet in the central part of the mountains.

The base of the Abo is poorly exposed and although the formation appears generally conformable with the underlying Magdalena group, there may be some local divergence or irregularity at the contact. The deep reddish-brown appearance of the Abo is distinctive. The formation ranges from about 550 to 1,100 feet in thickness in the Caballo Mountains, and is chiefly thin to medium bedded. Individual beds of sandstone and siltstone are lenticular and occur in a wide range of geometric shapes and dimensions. Sandstone beds are often crossbedded. Claystone is the dominant rock of the formation, but siltstone and sandstone are abundant. Lenses, nodules, and thin beds of gray-brown limestone are scattered in the red-brown claystone.

YESO FORMATION: PERMIAN.

The best outcrop of the Yeso formation underlies a nearly continuous valley between the Abo and San Andres hogbacks along almost the entire eastern foothills of the mountains. The formation ranges in thickness from 189 feet in the southwestern part of the Caballo area to 600 feet in the northern part. The thin section in the southwestern area may be due to nondeposition or erosional truncation of the upper beds of the formation. Yeso strata range from thin to thick bedded, and laminated bedding occurs in the gypsum units. They consist dominantly of sandstone and gypsum with lesser amounts of siltstone, limestone, and claystone. The sandstone is mostly tan to pale red although buff to white beds are common. Gypsum beds occur throughout the formation, but appear to be more abundant in the upper part. In many places gypsum beds are only a few feet thick and alternate with thin beds of sandstone. Elsewhere beds of gypsum are 20 to 30 feet thick. Light-gray to dark-gray very fine-grained limestone beds up to 20 feet thick are sparingly scattered through the section.

SAN ANDRES FORMATION: PERMIAN.

The San Andres formation crops out in a nearly continuous band along the eastern edge of the Caballo Mountains. The thickness ranges from 550 to nearly 1,000 feet.

The formation is thin to medium bedded and generally even or parallel bedded. It consists of about 75 percent limestone, which is slightly dolomitic in places. The limestone is light to dark gray on both weathered and fresh surfaces although some weathered surfaces have a light olive-drab appearance. The texture is chiefly very fine grained. In general the limestone is not cherty.

Thin units of thin-bedded limestone, claystone, or sandstone alternate with thicker units of limestone. The sandstone is mostly fine grained and yellowish brown or buff. Some lentils of claystone and siltstone are pale red and these in places include thick to massive beds of gypsum.

DAKOTA GROUP: UPPER CRETACEOUS.

The Dakota group, about 220 feet thick, rests disconformably on the San Andres formation. The basal unit is a medium-bedded, white siltstone about 26 feet in thickness. Above the basal siltstone is a unit which resembles the rocks generally referred to as Dakota sandstone in other parts of New Mexico. It is a thick-ledged, commonly laminated, pink to white sandstone, which weathers medium brown.

MANCOS SHALE: UPPER CRETACEOUS.

The Mancos shale, which ranges up to 500 feet in thickness and may rest disconformably on the Dakota group, is divided into two units. The lower shale unit is 42 feet thick, thin bedded, and contains several limestone beds which are from one to four inches thick containing a Greenhorn fauna. The upper unit consists of medium- to dark-gray shale containing olive-drab siltstone and shale. A few limestone beds one to six inches thick and a few light-gray bentonitic beds one-half to one inch thick occur in the unit.

MESAVERDE FORMATION: UPPER CRETACEOUS.

The Mesaverde formation rests on the Mancos shale. The change from marine shale to interbedded and lenticular conglomerate, siltstone, shale, and coal is locally abrupt where scour and fill relations at the base of the Mesaverde cut downward into the upper beds of the Mancos, but in most places there is a thin transition zone between the two. Shale beds of the Mesaverde are light gray to medium gray and weather to olive-gray or olive-brown hues. They are more continuous than the interbedded sandstone beds which are light gray to buff and weather to buff,

olive brown, and dark brown. The upper part of the Mesaverde consists largely of interbedded sandstone, shale, and conglomerate. The conglomerate beds contain pebbles of chert, quartzite, sandstone, and fragments of petrified wood.

McRAE FORMATION: UPPER CRETACEOUS (?) AND LOWER TERTIARY.

Cenozoic rocks in the Caballo Mountains area are confined to the flanks of the mountain uplifts, to the Rio Grande depression, and to the Jornada del Muerto.

The McRae formation of early Tertiary and possibly of late Cretaceous age probably is generally correlative with the Baca and Galisteo formations farther north. Rough estimates indicate that the formation exceeds 3,000 feet in thickness. It crops out at the north end of the Caballo Mountains around the base of Elephant Butte and along most of the shoreline of the Elephant Butte reservoir for several miles to the north of the dam. The upper limits of the formation have not been determined, and the lower contact appears to be transitional, disconformable, or sharp in different places. At the base there is usually one or two hundred feet of conglomerate consisting dominantly of assorted intermediate volcanic rocks. These beds are interbedded with shale or siltstone which is fairly typical of the shale and siltstone in the Mesaverde. Above the conglomerate unit the formation consists of many hundreds of feet of alternating purplish shale and buff sandstone beds. Conglomerate beds above the basal unit are rare and generally thin.

PALM PARK FORMATION: TERTIARY

At the south end of the Caballo Mountains a thick sequence of reddish-brown clastic rocks, which are probably younger than the McRae formation, crop out. These clastic rocks are known as the Palm Park formation. Palm Park strata have a high content of volcanic detritus and are interbedded with a few rhyolitic to basaltic flows. The relationship of the Palm Park sequence to the McRae sequence is unknown; however, the Palm Park beds probably are younger and probably are equivalent to some part of the Datil formation of the Socorro region.

THURMAN FORMATION: TERTIARY

Resting unconformably on the Palm Park formation and on the San Andres formation in the southern part of the Caballo Mountains area is a sequence known as the Thurman formation. This formation consists of white to light-buff rhyolite tuff-breccia, pinkish sandy clay, water-laid tuff, and tuffaceous sandstone. The stratigraphic position and lithology of the Thurman are similar to parts of the Datil, Espinaso, and Abiquiu formations to the North.

SANTA FE FORMATION: TERTIARY.

The Thurman formation appears to be overlain unconformably by strata of the Santa Fe formation. Santa Fe strata consist of alluvial fan and playa deposits which range from fanglomerate beds to sand, silt, and claystone. The color of the formation ranges from purplish brown to buff. The upper beds of the Santa Fe formation are bevelled by several levels of Quaternary erosion surfaces and stream terraces in the Rio Grande depression adjacent to the Caballo Mountains.

STRUCTURE

Structurally, the Caballo Mountains are a complex folded and faulted uplifted mountain block. The folds are largely the result of Laramide compression which formed the Sierra Madre Oriental. This compression resulted in overturning and thrusting as shown by the cross sections taken across the range (in pocket).

Six belts of overturning occur along the Caballo Mountains. They are diagonal to the over-all northerly trend of the range and are separated from each other by intervening areas in which the strata are relatively undeformed. Four of the belts are distributed in echelon along the east side of the mountain. They trend generally northwestward but swing locally nearly to the north. The four east-side belts are overturned to the northeast.

Two very incompletely exposed belts occur on the west side of the Caballo Mountains. The northern one of these is part of the Mud Springs Mountains structure. It is also overturned northeastward and was probably once continuous with one of the eastern belts. The other belt, on the west side, is overturned to the southwest.

The uplift of the Caballo Mountains was initiated in Miocene time by Basin and Range type of faulting. This block faulting which continued to a culmination in the Cascadian disturbance was synchronous with deposition of the Santa Fe formation and may be continuing as evidenced by Quaternary faulting. These faults are all steep to vertical and define various blocks which have moved differentially to each other.

PHYSIOGRAPHY

The area of the Caballo Mountains is divided physiographically into mountain uplands, elevated pediment surface, and incised stream valleys. The erosion surfaces were formed as the result of a long stillstand of baselevel of the ancient Rio Grande

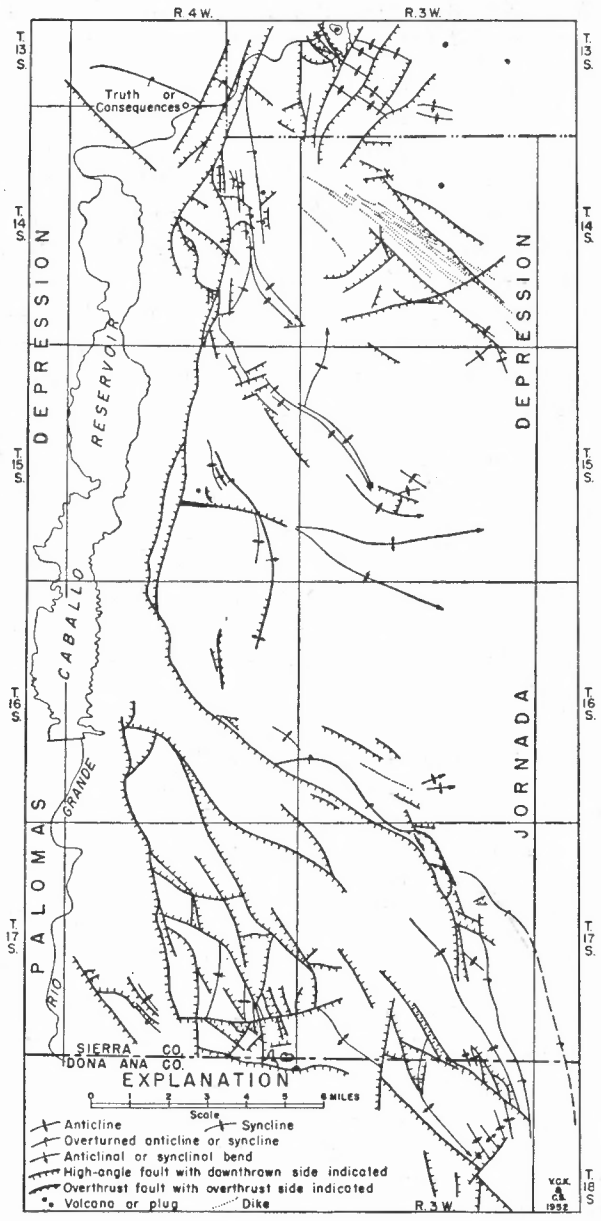


Figure 2. Principal tectonic features of Caballo Mountains.

and its tributaries in very late Pliocene and/or early Pleistocene. The Rio Grande may not have become an integrated through-flowing stream until late Pliocene or even Pleistocene time, and the widely accepted postulate that the Rio Grande once flowed through the Jornada del Muerto has been refuted by Kelley and Silver (1952, p. 184-185).

RESOURCES

Artesian water conditions occur in parts of Las Palomas Valley and the Jornada del Muerto. In Las Palomas Valley good artesian water exists as a result of infiltration into uptilted beds of the Santa Fe formation by streams tributary to the Rio Grande. In the Jornada del Muerto, artesian conditions result from a general synclinal structure. Wells drilled in the area have encountered moderate supplies of water of marginal quality which may be both sufficient and suitable for economic irrigation. Thermal springs at Truth or Consequences result from the transfer of heat by steam and vapors rising from emplaced hot igneous bodies through fractures which allow mixing with deeply circulating ground waters.

The Caballo Mountains are not highly mineralized but nevertheless contain scattered low-temperature hypogene, supergene, and placer deposits. The hypogene deposits occur as veins, irregular masses, and bedded replacement bodies of lead, copper, uranium, and fluorspar, and lesser amounts of gold, silver, and barite. The supergene deposits are mostly oxidation products derived from (1) lead ores, (2) copper ores, (3) manganoan carbonates, and (4) granitic rocks, and they include some vanadium and uranium deposits. Cave-filling deposits of calcite and gypsum and spring deposits of manganese also are present. Two kinds of placer deposits, gold and manganese, are known. The gold deposits are of considerable importance. The manganese deposits are relatively unimportant.

Coal of good quality occurs sparingly in the Mesaverde formation. Most of the coal seams are too thin to be profitably mined at present.

Possibilities for oil and gas exist in the basins adjoining the Caballo Mountains. Of these, the Jornada del Muerto appears structurally and stratigraphically the most favorable. The Paleozoic and Cretaceous formations offer both stratigraphic and structural possibilities which are as yet essentially untested.

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