ART. XXVIII.—*Notes on the Tertiary Intrusives of the Lower Pecos Valley, New Mexico*; by DOUGLAS R. SEMMES.

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INTRODUCTION.

In the central part of Chaves County remote from other evidences of igneous activity there occur two large and prominent dikes and an igneous sill intruding the Permian Red-beds that form the surface throughout the area. The two dikes are to be found on the eastern side of the Pecos in that comparatively level area broken only by occasional low sandstone—or caliche-capped mesas, that extends from the Pecos River to the bluffs of the Llano Estacado, some fifty miles to the east. Neither dike can be traced across the Pecos, but to the northwest on the western side of the river, as indicated on the accompanying map (fig. 1), there occurs a sill, now exposed by erosion to form a prominent north-facing scarp, which from its lithologic character appears to be related to the dikes, though there can be found no actual connection between them.

The topography of this part of the Pecos Valley is the characteristic red-bed type of mesas, "breaks" and intervening mesquite and cactus covered plains. The elevation of the river in this portion of its course is about 3,500 feet, from which the country rises rather rapidly to the peaks of the Sierra Blanca on the west, almost 12,000 feet above sea-level, and on the east to the Staked Plains,

about a thousand feet above the river. From the "breaks" of the plains, or the cap-rock, to the foothills of the mountains the Pecos Valley is approximately one hundred miles in width.

STRATIGRAPHY.

The following section represents the formations that are to be found in the area under discussion, though the entire section is not represented in any one particular locality. The two lowermost formations of the Pennsylvanian underlie the series in the Rio Grande Valley, but they are not exposed east of the divide and it is not certain that they are at all represented in the Pecos Valley.

FIG. 1.—Map of a portion of Southeastern New Mexico.

AGE	FORMATION	THICKNESS	LITHOLOGIC CHARACTER
Recent	Caliche	0-50	Surface layer of redissolved calcium carbonate, usually conglomeratic with numerous irregular limestone fragments and some water worn pebbles. Sometimes underlain by pebble beds and unconsolidated sands.
Tertiary (?)		10-40	Massive pebble conglomerates, locally known as "concrete." Usually found

AGE	FORMATION	THICKNESS	LITHOLOGIC CHARACTER
			capping mesas, lying unconformably upon the Red-beds.
Cretaceous	Sierra Blanca Series	1500-2500	Coal seams, interbedded sandstones and shale and occasional thin limestone with a massive, coarse-grained, buff sandstone near base (Dakota?) This series is sometimes found underlain by variegated shales, thin beds of limestone, sandstones and conglomerates; presumably the Morrison formation.
Permian	Red-beds	700	Red shales and sandstones with occasional thin beds of gypsum.
	(Gypsum series)	300	Massive white and reddish beds of gypsum with alternating red shales and sandstones, giving rise to a solution type of topography with sink holes, sometimes filled with water (Bottomless lakes).
Permian	San Andreas limestone	650	Massive layers of compact, grayish, fossiliferous limestone with occasional layers of shale and sandstone. Massive coarse-grained friable buff sandstone near base.
Pennsylvanian	Local Unconformity. Yeso	1000	Red shales underlain by alternating reddish shales, limestones and layers of gypsum. Highly folded where exposed in the vicinity of Capitan Mountain. Base unexposed.
Pennsylvanian	Abo	800±	Exposed near Alamogordo. Alternating red sandstone and red sandy shales.
Pennsylvanian	Magdalena Group (Madera limestone)	1500-2000	Exposed near Alamogordo. Massive bluish gray and dark bituminous limestone.

AREAL GEOLOGY.

Magdalena Group.—The Magdalena group as exposed toward the foothills of the Sacramento Mountains near

Alamogordo consists of a series of siliceous limestones, shaly limestones, and sandstone in the lower part, and massive gray and dark limestone (Madera) toward the top, the series aggregating some 1,500 feet in thickness.² This massive limestone is not exposed in the Pecos Valley, but it is possible that it has some representatives in this area now buried beneath the Permian sediments.

Abo Sandstone.—The Abo sandstone, the basal member of the Manzano group, is also exposed near Alamogordo. The formation consists of a series of red sandstone and sandy shales with occasional thin layers of gypsum. The Abo is unexposed in the Pecos Valley.

Yeso Formation.—This formation as developed in the Sacramento Mountains near Alamogordo consists of 1,000-1,200 feet of red shales, thin-bedded gray cherty limestone and occasional layers of massive gypsum. On the eastern flank of the mountain near Lincoln the series is again exposed in part and there consists of red shales and shaly sandstones some 200 feet thick overlying a series of alternating red and greenish shales and sandstones and thin-bedded fossiliferous limestones. That portion of the Yeso which is exposed in this locality aggregates about 1,000 feet in thickness and is sharply folded, lying unconformably below the San Andreas limestone. Farther away from the Capitan Mountains the Yeso appears to show less intense folding, and where last exposed near Picacho it is only slightly unconformable with the overlying San Andreas. There is little doubt that it will be found approximately conformable with the Permian series if encountered by the drill in the Pecos Valley.

San Andreas Limestone.—The Sacramento range, which is actually a dissected limestone plateau, is formed by continuous limestone formations from its western edge to where this limestone dips below the red-beds of the Pecos Valley. This limestone where exposed near Alamogordo has been correlated with the San Andreas, by Darton,³ which if correct undoubtedly indicates that the limestone developed from Roswell westward to the Sierra Blanca and the Sacramentos is equivalent to the

² N. H. Darton: A Comparison of the Paleozoic sections in Southern New Mexico. U. S. Geol. Survey, Prof. Paper 108, pp 31-55, 1917.

³ Op. cit. p. 50.

San Andreas.⁴ The San Andreas limestone of the Pecos Valley, extending across the Sacramento Mountain dips gently to the east and finally disappears under the Red-beds just west of the Pecos River. The tributaries of the Pecos have extensively dissected this limestone area and in the case of the Rio Hondo the San Andreas limestone has been completely cut through and the underlying Yeso exposed near Lincoln.

Red-beds.—Above the San Andreas there occurs an extensive series, 250 to 300 feet in thickness, of massive white and red crystalline gypsum with some interstratified red shales and sandstones. This east-dipping series of gypsum beds gives rise to a belt of striking solution topography characterized by extensive slumping and actual flowing of gypsum, sink-holes, caverns, and "bottomless" lakes, which crosses the Pecos River diagonally in the central portion of the area.

Beyond the gypsum belt the upper Permian red sandstone and shales form the surface eastward to the bluffs of the Staked Plains and there disappear beneath the cover of caliche. The normal dip is approximately 30 feet to the mile in a direction just south of east. The thickness of this upper sandstone phase of the Red-beds is difficult to determine but there are at least 700 feet of sediments represented.

Cretaceous Series.—In the Sierra Blanca coal field in Lincoln County the Cretaceous formations according to Wegemann⁵ consists of a coal-bearing series 630 feet in thickness comprising shales, sandstones, and occasional thin limestones throughout which occur several seams of bituminous coal. Beneath the coal-bearing strata occur shales, sandstones, and limestones, shales predominating, which aggregate 1,000 feet in thickness and which in the lower part have been correlated with the Benton. These formations are underlain by massive coarse-grained buff sandstones, 175 feet thick, often forming prominent escarpments, which has been tentatively correlated with the Dakota. Underlying the Dakota there occurs a series of variegated shales with thin beds of limestone, white

⁴ The San Andreas limestone of the Alamogordo section has been actually traced across the Sacramento Mountains and definitely correlated with the limestone west of Roswell by Mr. Dorsey Hager of New York City.

⁵ Carroll H. Wegemann: *Geology and Coal Resources of the Sierra Blanca Coal Field, Lincoln and Otero Counties, New Mexico*, U. S. Geol. Survey, Bull. 541, 1914. pp. 418-452.

sandstone and conglomerates which is considered a possible representative of the Morrison formation. These sediments lie in a structural basin and show frequent intrusions of igneous rock in the form of dikes and sills. The upper member of the Carboniferous series, the San Andreas limestone, is found out-cropping at varying distances from the coal field, but at no point was it found directly associated with the Cretaceous strata.

Tertiary (?) Conglomerates.—In the vicinity of Melena Station about 15 miles northeast of Roswell there occur massive beds of poorly consolidated gravel, locally known as "concrete", which lie unconformably above the Redbeds forming prominent mesas. This material though unfossiliferous is regarded as probably of Tertiary age.

Caliche.—The redissolved and poorly cemented limestone material that rests unconformably upon the older rocks, which has been termed caliche, is to be found capping the table lands throughout the Pecos Valley. Beneath the Caprock of the plains, which is of similar material, the caliche is underlain by unconsolidated sands and gravels of apparently Recent age. In the Pecos Valley the caliche is the only formation other than the river alluvium that is not cut by the igneous intrusions.

INTRUSIVES.

The igneous intrusives of the Pecos Valley in some cases form pronounced topographic features and are locally well known to the inhabitants of the area, who have in many cases prospected their contacts for the precious metals, but they have never been fully described in any publication with which the writer is familiar.⁶ These intrusives appear to be confined to the area north of Roswell, though the source or center of igneous activity from which they are derived is still uncertain. The two dikes are almost exactly parallel and extend eastward until covered by the drifting sands in the area just west of the Caprock, so that it is not all impossible that they might be derived from some center of igneous activity now concealed beneath the Plains. On the other hand other intrusives are to be found west of the Pecos and there also

⁶ The dikes east of the Pecos River have been mentioned by C. A. Fisher: *Geology and Underground Waters of the Roswell Artesian Area*, New Mexico, U. S. Geol. Survey, Water Supply Paper 158, 1906. p. 8.

Capitan Mountain and the other andesitic sills occurring in the Yeso series in that locality.

The Dunlap sill is approximately eighteen feet in thickness and shows two distinct phases; an upper differentiation phase about a foot or less in thickness, which is decidedly porphyritic, the feldspar occurring as phenocrysts, and of a composition approximating that of a monzonite. Beneath the upper phase lies the main body of the sill; a medium-grained dark resistant igneous rock, which from examination by a hand glass appears to have the composition of a diorite.

The contact effects are insignificant. Beneath the intrusive the baked shales are not over three inches thick though in places some of the effects of the intrusion can be seen in the shales a foot or two below the contact.

The sill is apparently conformable with the bedding and is gently inclined to the south; the normal dip in this area, however, is almost due east.

Sills in the San Andreas in Ruidoso Valley.—In the Ruidoso Valley about fifteen miles southwest of the juncture of Rio Ruidoso and Rio Bonito at Hondo the San Andreas limestone and the red shales and sandstones immediately underlying are intruded by numerous sills of general grano-diorite or quartz-monzonite composition. Some of these sills are of considerable extent, traceable for a mile or so in the steep walls of the valley, and varying in thickness up to fifty feet. These sills are of slightly more acidic character than the intrusives that have been described. Quartz is an abundant constituent and they are as a rule of coarse granitoid texture.

Sills in the Yeso near Arabela.—At the eastern foot of the Capitan Mountains near the Mexican town of Arabela the Yeso series occurs highly folded against the flanks of the Capitan intrusion (fig. 7). For a mile east of the contact these formations can be traced, frequently repeated by sharp and sometimes overturned folds. Farther to the east the series disappears under the San Andreas limestone, dipping 6° to the east. Between the folded Yeso and the San Andreas there occurs a series of red shales and sandstones about 100 to 200 feet in thickness, presumably upper Yeso, which shows comparatively slight folding; a transitional phase from the folded formations to those slightly tilted overlying ones.

Into this folded series numerous intrusions have taken

occur the more extensive though probably earlier intrusives that form the backbone of the southernmost extension of the Rockies.

Railroad Mountain Dike.—Railroad Mountain dike extends as a prominent ridge (fig. 2) from Sec. 4, T-8-S, R-26-E to Sec. 28, T-8-S, R-31-E, Chaves County, a distance of 30 miles in a general east-west direction. To the east it becomes lost in the sands before passing under the Plains and on the west it abruptly disappears beneath the

FIG. 2.—Railroad Mountain dike. Looking east.

river deposits just west of the Pecos and does not come to the surface on the western side of the river. As indicated by its name the dike forms a ridge sometimes sixty to eighty feet high and a hundred or more feet in width, much resembling an abandoned and partially dissected railroad embankment. The width of the dike is remarkably constant being approximately 74 feet at both extremities (fig. 3), which would indicate that the exposed portion represents only a fraction of the entire extent of the intrusion. Where the dike first appears just east of the Pecos the trend is N 89° E, striking directly for Capitan

Mountain. From this point eastward it trends more to the north running approximately N 86° E for a few miles and then N 78° E until lost in the sands.

The trend of the dike is approximately normal to the general strike of the formations through which it cuts, and in consequence the side walls vary in character with the formation. The contact zones are comparatively narrow, in some cases the contact effects being only recognizable a few feet from the contact. In other places typical contact zones are to be seen, the walls being thoroughly recrystallized and many of the more common contact minerals being developed. In most part, however, the effect of

FIG. 3.—Railroad Mountain dike as exposed along the eastern banks of the Pecos River. Looking east.

intrusion seems to have been merely a slight baking of the country rock. Numerous prospect holes have been dug along the entire length of the dike but little mineralization seems to have occurred. A few samples showed very low gold values.

The dike rock is a massive,, dense, dark blue, medium-grained, granitoid rock composed of pyroxene (diplage) and olivine in a felt-like mass of interlocking lath-shaped crystals of plagioclase (fig. 4). Considerable magnetite is scattered throughout, which is undoubtedly a primary constituent. Almost no secondary alteration other than a slight amount of sericitization has occurred, a fact that explains the resistance of the dike rock to erosion and its consequent occurrence as a prominent topographic fea-

ture. The rock should be classified as an olivine gabbro. The interlocking feldspar aggregate is quite common in dike rocks (diabases), but the composition is of a more basic character than most of the other intrusives of the area.

Devil's Racetrack Dike.—This dike extends from Sec. 15, T-10-S, R-26-E to Sec. 7, T-10-S, R-29-E, Chaves County, a distance of approximately 15 miles. Like Railroad Mountain it can be traced eastward until lost in the

FIG. 4.—Photomicrograph of Railroad Mountain dike. 50 X. Showing diabase (D), olivine (O), and magnetite (opaque) in a matrix of interlocking plagioclase crystals (P).

Mescalero sands, and to the west it disappears beneath the caliche-capped plains east of the Pecos River, some 15 miles northeast of Roswell. No traces of it can be found in the gypsum bluffs that form the east bank of the Pecos about six miles west of the point where it disappears. Devil's Racetrack in contrast to Railroad Mountain forms no topographic feature but on the contrary is sometimes expressed on the surface by a slight depression, the dike rock being more readily eroded than the country rock.

The contact effects, resulting in the baking of the wall rocks for some feet from the contact, have given rise to two belts of resistant rock—the contact zones—between which lies the dike forming a slight depression, the whole resembling somewhat a modern race-course. Toward its western end the width of the dike is 32 feet but it widens to the east and where last seen showed a width of 47 feet. This increase in thickness to the east is decidedly suggestive and indicates that both of these dikes are possibly

FIG. 5.—Photomicrograph of Devil's Racetrack dike. 50 X. Showing diabasic texture. Magnetite and secondary amphiboles in the interstices of the lath-shaped feldspars (P).

associated with some concealed center of igneous activity farther to the east. The trend of the Devil's Racetrack is exactly the same as that of Railroad Mountain (N 89° E) toward its western exposure. About Sec. 15, T-10-S, R-28-E, the trend changes to N 85° E and continues eastward in this direction as far as it can be traced. The contact effects are confined to zone varying from 1 to 10 or 12 feet in width and consist for the most part of a mere baking of the country rock. Numerous prospects have been

made along this dike but no appreciable mineralization appears to have taken place other than a limited amount of pyritization.

This intrusive is a fine-grained, slightly porphyritic, bluish gray rock composed of augite and magnetite in a matrix of lath-shaped feldspar crystals, showing typical diabasic texture (fig. 5). Extensive secondary alteration has taken place, the feldspars being highly kaolinized and the augite almost wholly altered to secondary amphiboles, consequently the rock is easily weathered giving rise to no topographic feature other than a slight depression where the dike cuts a resistant formation. The composition is intermediate between the andesites and the basalts, but

FIG. 6.—Dunlap sill. Looking east.

neither megascopically or microscopically does it resemble a normal basalt, so the intermediate term augite-andesite is adopted instead.

Dunlap Sill.—About eight miles south of the post-office of Dunlap there occurs a sill intruding the Red-beds, that can be traced for almost four miles along its outcrop from Sec. 1, T-4-S, R-22-E, through Secs. 32 and 33, T-3-S, R-23-E, to Sec. 3, T-4-S, R-23-E, and throughout most of the area it forms a prominent scarp facing north (fig. 6). This intrusive like the dikes already described is not directly associated with any center of igneous activity, and it lies some fifty miles northeast of the extensive, though decidedly more acidic, intrusive that forms the

place, some of which are of considerable extent. The general composition of these intrusions, which are predominantly sills, is that of an andesite,⁷ and the sills are conformable with the stratification being also highly folded, showing conclusively that the intrusion took place prior to the folding. Andesite sills were also found in the red shale series lying just under, and approximately conformable with, the San Andreas limestone.

Sills and Dikes in the Sierra Blanca Series.—The Sierra Blanca coal-bearing series which is regarded as Upper Cretaceous or possibly of post-Laramie age is widely intruded by sills and dikes of the general composition of those found near Capitan (diorites and monzonites). Just east of Capitan on the Lincoln road an andesite dike trending N 24° E and about 15 feet thick crosses Salada

FIG. 7.—Generalized cross-section from Capitan Mountain to Agua Azul, showing the crumpled Yeso strata underlying the relatively undisturbed San Andreas limestone. Scale 3 inches to the mile.

Creek, cutting the massive sandstones of the lower part of the series. Just west of Capitan on the highway to Carizozo the coal-bearing upper series is intruded by dioritic sills twenty-five or more feet in thickness. The series has also been locally faulted and the coal in many places shows the effects of the intrusion.

Summarizing the above, the intrusives of the Pecos Valley that are apparently of related origin and similar age, inasmuch as they are generally similar in composition and mode of occurrence, are seen to occur not in any one formation but in every series represented in the area, with the exception of the recent sediments, from the Yeso beds near Capitan to the Upper Permian Red-beds just west of the Cap-rock, and the Upper Cretaceous or possibly Eocene coal-bearing formations of the Sierra Blanca series.

⁷ The term andesite is used by the writer to include also the basic andesites (augite-andesites), classified as basalts by some writers.

STRUCTURE.

The structure of this portion of southeastern New Mexico is that of a gently inclined east-dipping monocline rising gradually on the west from the Pecos River and the Red-bed area beyond to the crests of the Sacramento Mountains, and there breaking off forming steep scarps to the west. Toward the lower part of these escarpments, near Alamogordo, the Paleozoic series from the Pennsylvanian down lies conformably beneath the Permian and rests upon the pre-Cambrian granites.

On the eastern side of the divide the exposed members of the Manzano group show structure in wide contrast to that on the western slope. The pronounced unconformity below the San Andreas limestone is very striking. Fan-shaped and overturned folds frequently occur, the whole series being repeated many times within a short distance. The lower portion of the Yeso series is unexposed but at least 800 feet of these folded sediments can be recognized. Nearer the Pecos River in the eastern portion of the district the general east dip of the Permian strata is broken by occasional sharp and elongated anticlinal ridges, the best example being the Border Hills, 25 miles west of Roswell. These anticlines are similar in strike and in structure, being sharp, fan-shaped folds, expressed in the surface as prominent ridges, sometimes rising several hundred feet above the surrounding country, and showing a general trend of N 10° E to N 40° E.

Toward the west of this eastward-dipping monocline of Carboniferous strata, and encircling the peaks of the Sierra Blanca, the Cretaceous coal-bearing strata lie in a structural basin some thirty miles long (N-S) and twenty miles wide. A large amount of igneous material showing variations in composition and mode of occurrence has been intruded into these sedimentary series. This igneous material can readily be divided into those larger intrusives of more acidic composition that form the Sierra Blanca, Capitan, Jicarilla and Pajarito Mountains; and the smaller or more basic intrusives such as have been discussed, which dissect and permeate all of the sedimentary rocks of the area. These larger intrusives are probably older than many of the smaller ones, for near Nogal Peak the larger monzonite intrusive is cut by later diorite (?) dikes.

AGE OF THE INTRUSIVES.

Toward the end of the Cretaceous mountain-making movements were inaugurated throughout the entire area

now occupied by the Rocky Mountains and these movements were accompanied by extensive intrusions of batholithic character outlining many of the present ranges. Similar movements continued and a great series of minor intrusives and some lava flows were injected into the Paleozoic and Mesozoic sediments surrounding the area involved. This period of igneous activity extended throughout the middle of the Tertiary with unabated intensity, and was represented still later (in late Tertiary, Quaternary and Recent times) by the outpouring of the extensive basaltic flows of northern and western New Mexico.

That the larger intrusives of the Sierra Blanca region are of post-Cretaceous age is evident from the fact that they intrude Cretaceous sediments. Lindgren (et al.) considers⁸ all of the monzonitic and dioritic intrusives of similar character to these to be early Tertiary age. If the upper member of the Sierra Blanca is actually of post-Laramie age as intimated by Wegemann⁹ some of the dioritic intrusions are undoubtedly late Eocene or even younger in age. From field observations the writer feels that the more basic and less extensive intrusives (diorites and gabbros) are younger than the more acidic intrusives (monzonites, quartz-monzonites, and grano-diorites) forming the mountain masses. This is borne out by the fact that diorite dikes intrude the monzonite near Nogal Peak. Moreover, the fact that these two classes of intrusives are distinct in composition and mode of occurrence suggests that they represent earlier and later stages in igneous activity.

Incompetency near Lincoln.—As has been noted the Yeso formation, intruded by the large monzonite intrusion that forms the Capitan Mountains, is sharply folded though the overlying San Andreas limestone is only slightly tilted. Moreover the Yeso is extensively intruded by andesite sills that are folded with the adjacent strata. This shows quite conclusively that the folding must have taken place subsequently to the intrusion, that is in early Tertiary time. The overlying limestones, however, deposited in the Permian have not been folded. The only adequate explanation of such structural conditions that suggests itself to the writer is that the relatively incompetent Yeso shales, gypsum beds, and lime-

⁸ Waldemar Lindgren, L. C. Graton, and C. H. Gordon: The Ore Deposits of New Mexico, U. S. Geol. Survey, Prof. Paper 68, pp. 35-40, 1910.

⁹ Op. cit. p. 428.

stones crumpled between the massive San Andreas limestone above and the igneous rock, or even the massive sandstones of the Abó and limestones of the Magalena group which should be found below. This explanation is supported by the fact that the Yeso crumpled series changes gradually through an upper series of slightly folded red shales to the unfolded limestone above. If there was an actual unconformity and accompanying erosion interval one would expect a sharp contact between the two, but such a break cannot be found. Incompetency on such a scale is unusual, possibly unique, but the existing structural conditions are difficult to explain in any other way.

Age of the Folding in the Roswell Area.—The two dikes east of the Pecos and the sill near Dunlap can be considered, therefore, to be later Eocene or younger in age. It is possible that these intrusions may represent later stages in Tertiary igneous activity, when the basaltic intrusives and extrusives originated, and may even be derived from some source quite unrelated to intrusives of the Sierra Blanca area, such as a concealed center of igneous activity under the Llano Estacado. In this case the dikes may be of middle or late Tertiary age.

The age of the folding that has given rise to the peculiar and characteristic sharp, elongated anticlines in the limestone area west and southwest of Roswell cannot be definitely ascertained, but it is not unreasonable to suppose that at the time of the intrusion of the larger bodies of igneous rock and the crumpling of the Yeso, the stresses that were set up in the overlying limestone were relieved by buckling along lines roughly parallel to the trend of these intrusions. The age of the folding in this case would be early Tertiary, though it is quite possible that it may have occurred at a much later date, for there are indications of even Recent movements expressed in the caliche that occurs throughout the area. The determination of the approximate age of this folding should be of interest from the point of view of oil and gas production, for should it be conclusively shown that the folding in this area is of comparatively recent age one might reasonably conclude that relatively little oil would now be entrapped.