THE GEOLOGY OF THE WHITE SANDS OF NEW MEXICO

EAST of the San Andreas and Organ mountains of New Mexico is an extensive valley that has been the subject of much discussion from the practical as well as the theoretical point of view. The writer is not aware that any competent geologist has had the opportunity to make an exhaustive study of its unique features and ventures to put on record the results of a somewhat careful if cursory examination of the yalley and its environs.

Our first visit was made by wagon from Socorro, the seat of the county of the same name, by a route which afforded ample opportunity to observe the varied geological conditions of the region to the north and east. East of the Rio Grande, after leaving the immediate valley of the river, the Tertiary red marls are encountered, and lie in rather low terraces upon the foot of the greatly disturbed red beds of Permian and Triassic age. These beds are tilted and greatly faulted, leaving one in doubt as to the sequence at this point, especially as there are curious beds of fire clay and shale filled with a varied flora of carboniferous habit consisting of numerous species of Lepidodendrids as yet not worked out specifically.

The lower part of the Permian is composed of limestones and sandstones capped by anhydride and gypsum beds, the former being in some places massive and upwards of fifty feet thick. Extensive exposures of what is apparently carboniferous limestone constitute the principal axis of the low range at this point, and are followed by the red beds over a large area on the eastern side. These beds, as everywhere in the territory, are impregnated with salt and saline alkalis as well as gypsum. The springs are nearly always salty, and lower flats are covered with "alkali." Passing southward, in the immediate valley of the Rio Grande, near San Antonio, is the remarkable basin of so-called tripoli described by the writer some years since. There is no reason to alter the opinion then expressed that this fine-grained scale-like deposit is the result of the attrition of the floating pumice which forms the surface of the deposit. In fact, in several other places in the Rio Grande valley similar beds on a smaller scale have been encountered, and in each case the material could be traced directly to the acid scoria of the period of trachite eruption.

To the southeast we pass to the celebrated Carthage coal belt, at which point a collection of Cretaceous fossils was made, but, as they were not found in immediate connection with the coal beds, it is impossible to decide what is the age of the coal upon that basis alone. However, a little farther south in the vicinity of Engle and East of the Caballo Mountains fossils of the Laramie age seem to prove that the coal fields at this point are of that period.

At San Marcial and at frequent intervals down the valley are basaltic cones which have broken through the Tertiary gravels and marls and supplied the material for the sheets of lava so characteristic of the entire territory. It is easy to see that they follow in a general way axes of weakness extending north and south, but it is not so easy to determine the reason for a sudden return to highly basic conditions after a gradual increase in acidity in the volcanic flows of the territory. As the writer has shown in several papers, the sequence is from an augite-andesite or diabase through trachite and pitchstone and obsidian to rhyolite. The soda-syenite and phonolite may perhaps form a transition from the andesite, though the occurrence of the soda series is less general

It suggests itself to the writer that the serial arrangement is to be attributed to an invasion of the silicious crust by the internal heat, and that progressively less of the deeper material was involved in these flows until it may be said that that chapter of igneous activity was closed by the rhyolite eruptions. Long after, perhaps as a result of the differential strain of glaciation and its attendant shifting of the axes of rigidity of the crust, deep crevices were formed entirely through the acid crust and permitted a slow and relatively quiet overflow. This method of eruption would account for a considerable degree of fluidity of the lava and for the very slight surface disturbance. However this may be, the flows of lava, usually of slight thickness, are often of enormous extent, and where water has had access to the loose materials beneath, the characteristic *mal pais* results.

Our way is now across the Jornado del Muerto, the perils of passage being greatly reduced by the sinking of wells for ranches at various places, though the terrors of a blizzard on these barren treeless plains needs but to be experienced to be appreciated. Though comparatively arid and seemingly barren, the short grass furnishes a good subsistence to many herds of both cattle and horses.

Rising by a rather moderate slope from the plain are the foothills of the great range which begins with the Sandias east of Albuquerque and is continued in a broken line by the Manzanos, the Oscuros, the San Andreas, and the Organs. In the Sandias and Manzanos the granite, everywhere lying at the base of the stratified rocks, so far as known, in the territory, is exposed in an extensive escarpment on the east side of a very important fault line and the superincumbent stratified rocks dip rapidly to the east. In both the ranges mentioned the rock lying upon the granite, or its gneissic or schistose equivalent, is a quartzite whose materials seem not to have been derived from the subjacent granite, but from a schist or quartz rock which we suppose to have been the superficial portion of that series. The age of the quartzite, as well as that of the granite, must at present remain a matter of conjecture in spite of poorly preserved fossils in the limestone layers found in one or two instances in the midst of the granite. Reposing on the quartzite conformably in the Sandia and Manzano ranges is a silicious series with a few limestone bands whose fossils seem to be of undoubted Coal Measure age. This is followed by a dark conchoidal limestone with shales having a fauna similar to that of the Upper Coal Measures in Ohio as will be more particularly set forth in another place. The lower series we have called the Sandia series from the place where best seen. Some distance above the dark lime is a sandstone or conglomerate which is rather inconstant in thickness and may be absent, but which roughly marks the transition to the permo-carboniferous as generally developed in all the ranges under consideration. This Coyote sandstone is particularly well seen in the canyon of that name in the south end of the Sandias. Above this is the large series of massive gray and silicious lime at whose base it is usual to find a large form of Fusulina and, a little higher up, a well defined zone characterized by the bryozoa preserved on the faces of the cleavage slabs. Here begin the evidences of a transition to the Permian as indicated by the presence of *Mekella striatocostata*, *Terebratula bovidens*, *Productus punctatus*, and a variety of forms which are mingled with fossils also found in the carboniferous below. At the top of the gray lime is a large series of coarse, red quartzites and sandstones interbedded with dark earthy limestones and shales. There are few fossils except petrified wood and the few found still preserve a carboniferous habitus. This Manzano series is everywhere in evidence where a sufficiently high horizon is reached but is often removed from the crests of the range while it occurs in the eastern faulted extension. Following this is the group of red quartzites, sandstones, shales, and marls which we have recognized as the equivalent of the "red series" of Texas and Kansas. Three divisions can be made out in all parts of the territory examined which have been named from their prevailing or characteristic color, though it is not to be supposed that the color mentioned is constant. The lower or "red bed" division still retains some bands of limestone or lime breccias, the latter being a very characteristic element. Some 500 feet may be estimated as the average thickness of this division and prior to the work recently done in the valley of the white sands we had no definite evidence as to the age of the entire division. We only knew that a narrow bed of quartzite near the base at a point east of the Sandia Mountains contained the well-known Permian forms such as *Bakvellia parva*, *Myalina attenuata*, *Pleurophorus* *subcuneatus*, etc. The major portion of the series proved obstinately barren. At the top of this division there are found in the most widely distant parts of the territory enormous deposits of gypsum and salt. In fact the presence of salines may be said to characterize the series, but especially at the passage from the red into the chocolate beds above it. The chocolate series has a thickness of at least 600 feet and passes through quartzites and gray and red sandstone layers into the loose vermilion marls and clays of the upper division. So far, we have no positive evidence as to the age of the two upper divisions, but may presume the chocolate beds to be Triassic and the vermilion division to represent whatever of Jurassic time is accounted for in the territory or at least in the central portion.[1]

South of the Manzano range the continuity of the uplift is broken so that in the Fra Cristobal and Caballo mountains near the Rio Grande and in the Oscuro range farther east the dip is, as in the Sandias and Manzanos, to the east while in the San Andreas, occupying an intermediate position farther south, the dip is to the west so that the high escarpment with its granite and schistose base faces the great salt plain.

In the interval between the range bordering the river and the Oscuro Mountains we have abundant evidence of the existence of the Cretaceous with its lignitic coals and it may be assumed that the Cretaceous also extends southward on the west side of the San Andreas, though nowhere exposed in the *Jornardo del Muerto*. Passing eastward lower horizons gradually emerge till, as we enter the interval between the north end of the Andreas and the south end of the Oscuros, the red beds are seen in the form of low hills with a dip to the east at the western foot of the Oscuros. Underneath is a part of the Permo-carboniferous. It appears, therefore, that the Oscuro range is separated by a fault line from the axis of the Andreas. On the west side of the San Andreas the red beds are represented as is shown by the extensive deposits of calcium anhydride in the foothills.

[1] It will be remembered that Professor Cope in 1875 identified part of this series as Triassic and that Dr. Newberry described Triassic plants from New Mexico.

The eastern escarpment of the Andreas is bold and irregular in the extreme but the fault which created it seems to have been wavy so that a crenulated or sinuous aspect is presented to the plain. The granite in some instances seems to have escaped in pinnacled or columnar form and throws off the restraining influence of the stratified rock to appear in jagged peaks. This is particularly true in the Organ Mountains where, however, there must be added the influence of a later trachytic overflow. Our examination of the San Andreas was cursory but was sufficient to show that the thickness of the stratified series is greater than in the Sandias and Manzanos. The lower portion is composed of quartzites and silicious shales which may be compared with the quartzites in the Manzanos. Above this is a large series of gray cherty limestones and quartzites of an entirely different texture and appearance. This has baffled our search for fossils in the Andreas and the Caballos where it is also well developed but, fortunately, we have been able to discover in the upper part of this series on the eastern side of the salt plain fossiliferous bands which place the age beyond doubt. Spirifer Grimesi, Leptaena rhomboidalis and other well-known Burlington brachiopods are associated with crinoids of that period in great abundance. Some of the bands are practically composed of the débris of the crinoids.

Above the Burlington there seems to be a hiatus, for the next species encountered are distinctively Coal Measure forms and the sequence from this on to the top is as in the ranges farther north though there seems to be a tendency for the limestone to encroach on the sandy elements and for the individual components to thicken toward the south, a fact which we interpret as indicating deep-sea conditions.

Attention has elsewhere been called to the method of occurrence of the copper found so widely scattered through these ranges. It was shown that the deposits of copper which have attracted so much attention were formed in veins that extend from top to bottom of the sedimentary series but do not seem to cut the granite, at least to any depth or with any regularity.

These veins are so regular that it is conceived that they may be best explained as the result of warping or shrinking in the sedimentary series and it seems certain that they have been filled from above. The vein matter is chiefly calcite, fluor spar, siderite and barite and it is chiefly at the intersection of the vein with a band of iron-filled quartzite, reposing on the granite and forming a definite selvedge to the sedimentary series, that the copper is deposited. The ores include nearly all the common copper compounds, calchocite, malachite, azurite, bournite and cuprite predominating. Here, as in Hannover and Santa Rita, it seems indubitable that the iron, accumulated by leaching, has been the agent in precipitating the copper.

Between the Organ and San Andreas mountains there is an area on either side where the granite is laid bare and it is true that some show of copper may be found in crevices and basins superficially on the granite. It is probable that all, or a great part, of the copper of the two ranges has been originally derived from the red-bed series (Permian and Triassic) by infiltration, for the original existence of the cupriferous series on top of the strata now remaining in the ranges is indubitable. Dikes of diorite cutting through the granite and sedimentaries along or near the fault line have caused portions of the latter to lie in irregular fragments along the foot of the escarpment to the east, the strata dipping towards the dike which served to pry them from their original position.

Standing upon a jutting eminence of the San Andreas and turning eastward one looks out upon a scene difficult to parallel. At one's feet is an enormous plain, apparently as level as a floor, over forty miles wide and extending as far as eye can reach to north and south. On the southern horizon rise the Jarillas Mountains which only partially interrupt the plain, while to the northeast are the snow-capped peaks of the Sierra Blanca. Northward the plain is narrowed by the eastward intrusion of the Oscuro range while it is possible to make out the dark area of basalt which covers that part of the plain to the east and southeast of that range. This is the widely-know "*mal pais*" of

Socorro county which has proven such an effectual barrier to communication between the Rio Grande valley and the growing region of White Oaks. South of the *mal pais* is a great white sea on which one can fancy the glint of white-caps. Such a body of water being out of the question the uninstructed observer would surely think himself the victim of a mirage but we recognize in the snowy area the famous white sands. Curious and conflicting stories are current respecting the area but the truth is not less interesting. We had already been forced to the conclusion that the true origin of the saline and gypsum beds is to be sought in the red series above mentioned. It seemed at first, however, that the geological relations would prove baffling.

Rising abruptly from the level plain on its eastern side are the foothills of the Sacramento range near which pass the trains upon the newly-finished El Paso and Northeastern railway. The escarpment is nearly perpendicular and the dip is very slight and to the east. The bottom of the sedimentary series is not reached, at least in this vicinity, but it is evident from a comparison of this with the western escarpment that the base is not far distant. The section is given in detail below but we were very fortunate in coming upon a locality where the lower portion of the section is fossiliferous About 560 feet from the base, at Dog Canyon, some 12 miles southeast of Alamogordo is a band of crinoidal limestone which, together with the gray lime and quartzite above it, contains numerous, though poorly preserved fossils. Among these enough forms were identified to determine the limestone as Burlington. As nearly as we could determine the Burlington is represented by at least 250 feet. Several intercallary sheets of igneous rock (diorite, with porphyritic hornblende) penetrate the strata and obviously connect with a boss farther east and higher up the canyon. The influence of the intrusive may account for the amount of chert seggregated in this portion of the section but, for whatever cause, the limes are chiefly highly silicious and quartzite has replaced former limestones. Above the Burlington, which is entirely absent farther north, is the entire series of Coal Measure limestone and sandstone as seen in the Sandia range except that the deeper sea conditions have expressed themselves in greater thickness of limestone. The fossils in the lower part are of mid-carboniferous types but pass somewhat gradually into the assemblage which we have characterized as Permo-carboniferous. *Meekela*, *Terebratula bovidens*, *Productus punctatus*, a large *Bellerophon* and many other familiar forms indicate an approach to the top. Above the measured escarpment but inaccessible to our reach is a series of what appear to be yellowish sandstones or quartzites which may confidently be referred to the Manzano series at the top of the Permo-carboniferous. Northward the dip rapidly veers to the northeast and thus the several horizons drop below the surface and bring still higher ones than those seen at Dog Canyon within reach. About 16 or 18 miles west of the main escarpment is a low ridge of hills which prove to consist of carboniferous limestone but bearing evidence on their western aspect of the fault which brought the plain down to a lower level. This ridge is most instructive in showing that the fault was not a single break but by steps or successive faults. Wells in the plain to the west all show the existence of the red beds both by the presence of salt (often strong brine), but also by the red color of the marl brought to the surface. North of the outlyer spoken of is a most interesting spring which has built up for itself, geyser-like, a mound of some thirty feet above the general level from which issues a quantity of warm and highly saline water which flows into a depression and, sinking from view, leaves a large salt and alkali flat. Other similar lakes are grouped in the neighborhood. The actual character of the deposit is generally masked by a calcareous marl of white or gray color which forms a crust over the entire plain and is highly charged with salts except at the immediate surface.

But passing northward and observing several other saline springs similar to the one described, the route carries us through the intensely modern "boom" town of Alamagordo with its great sawmills fed from the Sacramento Mountains by a spur railroad and the equally typical old Mexican town of Tularosa where nearly every house is of adobe. The intense red color of the adobe awakened our curiosity and led us to the examination of the escarpment to the east and north. As we hoped, the dip had sufficed to bring to the general level strata which at Dog Canyon were out of reach and the lower third of the red series with its capping of gypsum and salines is at the foot of the section. The following is the section as casually examined during our visit—a section which will yield a large suite of interesting fossils of decided Permian facies, though well-known carboniferous forms extend throughout. Commencing at the bottom, we have first a poorly exposed series of silicious shales and thin-bedded limestones in which is a characteristic Permian assemblage including *Myalina permiana*, *Myalina attenuata*, *Pseudomonotis hawni*, *Aviculopecten occidentalis*, etc.

Then follow, as we ascend:

Reddish shales and loose sands	15 feet
Limestone	6 "
Greenish sandy shale	10 feet
Coarse conglomerate with pebbles of granite, etc.	5 to 10 "
Purple red sand with pebbles	20 to 25 "
Earthy limestone	2 "
Loose red sand	18 "
Coarse red conglomerate	4 to 5 "
Red sandstone	8 "
Loose red sand and shales	18 "
Conglomerate	4 "
Limestone	2 "
Greenish sand	12 "
Earthy lime shales and sand	5 "
Limestone and calcareous shale	6 "
Sandy shale and green sands	35 to 40 "
Well marked bench of gray lime	8 "
Red shale including a very irregular conglomerate	4 to 8 "
Thin bed of lime	1 foot
Green fissile shale	6 feet
(Gypsiferous marl, probably surface deposit)	00 "
Limestone and shale with numerous small fossils	6 to 8 "
Brown or red shale with numerous fossils	35 "
Sandstone	8 "

Shale	6 feet
Sandstone	6 (?) "
Limestone	1 foot
Green sandstone with calcareous band	20 feet
Calcareous zone	00 "
White sandstone	4 "
Shell limestone fossils	1 foot
Nodular marl	15 feet
Nodular limestone	2 "

Our ascent ended here but beyond appeared the gypsum beds reposing upon red and white marls as in the Nacimiento region and elsewhere. Still above and forming separate terraces are the chocolate and vermilion beds, and at the top of the section the lower Cretaceous. The creeks or arroyos which traverse the gypsiferous horizon come laden with salt which is deposited as a white coating upon their beds and banks.

Having satisfied ourselves both as to the age and the character of the deposits which underlie the great plain, we undertook a study of the plains themselves. At the southern end of the *mal pais* which forms the northern boundary of our field of work, numerous springs gush out from beneath the thin sheet of black basalt. These springs differ from those from the salt valley itself, in that the water is not warm nor appreciably salty. It is apparent that the lava has served to retain the water which, on making its way beneath the sheet, has excavated channels in which the water may be heard rushing by one crossing the lava. One of these streams in particular, at Mal Pais spring, forms a considerable creek which supports a varied plant and animal life including fish of considerable size and several crustaceans (Gammarus or the like). The water, before it flows many rods, becomes distinctly salty and bitter. At a little distance to the south begins an area of depression which is forty miles long and receives the drainage from all directions. This whole area is covered with saline efflorescence while all the shallows, when dry, as they are most of the year, have considerable deposits of salt on the surface and the subsoil or under clays are infiltrated with alkaline salts the nature of which will be fully discussed in another place

About one mile from the Mal Pais spring above mentioned is a small salt lake which has furnished the salt for ranches for a radius of many miles during the historic period and at our visit the surface was covered to the depth of an inch or so with pure crystalline chloride of sodium. Still west and forming the western limit of the visible saline beds, is a drainage arroyo whose source seems to be in the red beds that emerge west of the Oscuro Mountains and conveys their saline water to the basin of the sands. Along the course of this arroyo are numerous salinas and alkali flats and these gradually broaden to form what may be described as one vast alkali and salt plain where brine stands for part of the year. Other arroyos come in from the west in some of which, even at the time of our visit, was a considerable quantity of flowing water which is a strong brine unfit for cattle even when accustomed to drink from the saline springs which unwonted animals will reject. Where these arroyos enter the salt lake and along the shores of the lake are bluffs of erosion some of which are over twenty feet high. In these exposures we encounter the red bed formation with its marls and gypsum deposits. Large quantities of pure crystalline gypsum are here exposed and the marls are alkaline and saline. We have therefore local proof, as well as the most conclusive evidence from the environs, that the whole of the plain is in or near the horizon of gypsum and salt that separates the lower from the middle member of the red or saline series.

In the salt flats the ribs of gypsum rise in successive ridges, and the action of the elements soon breaks up the exposed crystals into small grains which are carried by the winds hither and yon. This characteristic of the salinas accounts for the most curious and notable of the many peculiarities of these plains, namely the white sands. These have been attributed to the action of springs and the material has been supposed to have crystallized from solution. It has been suggested that the sands have been collected by floods, but a short examination shows that these great drifts are simply sand dunes collected from the gypsum sand formed as above stated on the surfaces of the lakes. The salt and alkaline salts are also driven with the gypsum but on account of their solubility they do not remain in the dunes. These dunes lie to the south and east of the flats whither they are driven by the prevailing winds and not only cover a large part of the salinas themselves, but form a growing fringe to the east and south. The dunes are, in the majority of instances, very pure gypsum though there is a small commingling of earthy impurities. The soil underneath is impregnated with salt and soda and salt lakes are scattered over the area covered by the dunes. The intervals between the crests of the ridges support a scanty but very interesting vegetation. Near the southeastern angle of the sands is a very important salt lake which has been known as a source of salt for the ranches for many years. The north and south extent of the "white sands" is about 35 miles while the greatest breadth at the southern margin is about 18 miles. The lines connecting the extreme points are irregular, enclosing roughly a triangle of about 350 square miles. To this may be added nearly as much more of saline land on the west and in isolated areas to the south. The whole plain is geologically of the same nature, but, inasmuch as it is either higher than the basin or is more completely drained (to the south), the saline ingredients are not brought to the surface.

East of the Jarillas Mountains this plain again gives external evidence of its subterranean supply of salines while far to the north, beyond the covering of lava, there are depressions of the same character and of the same geological age and nature. The fact that such depressions occur in New Mexico only in connection with the red beds leads to a suggestion that may be worthy of consideration. It is evident to anyone who has studied the geology and geography of the territory that it is, as Major Powell said long ago, the best drained region in the world. The comparative newness and permeableness of its strata all militate against the formation of local basins. There has been no glaciation to produce local lake reservoirs. Erosion has kept well in advance of secular changes of level and barriers of local origin do not prove capable of retaining the waters which come in torrential plentitude when they come at all. Some explanation must be sought for the basins found in the saline areas. It might be supposed that such explanation would be found in the depressions resulting from the post-Tertiary lava flows which occur over the entire territory. To this it may be replied that the basalt is certainly of deep origin, for the preceding flows were all acid and the basalt overflows are essentially similar among themselves and demand a common origin at a depth. Moreover the distribution of the flows indicates that the orographic lines of weakness opened were of almost continental extent. The depressions due to the outflow of basalt would not account for the local basins referred to and we are driven to the conclusion that these slight depressions are due to the effect of the removal of the soluble ingredients in these beds themselves.

The discussion of the economic aspects of these beds will occur in the forthcoming bulletin of the University Geological Survey of New Mexico.

C. L. HERRICK.

DESCRIPTION OF PLATES

PLATE I.

Sketch map of the region of the "White Sands" including part of Dona Ana, Socorro, and Otero counties, New Mexico.

PLATE II.

Mostly Permian fossils from exposures near Tularosa and east of the Sandia Mountains in Bernalillo county. These plates are given to illustrate the fauna rather than as a basis for a discussion of the species figured, which have as yet been subjected to no critical study.

FIG. 1 *Pseudomonotis* n. sp. (*costatus*).
FIG. 2. *Bellerophon* sp.
FIG. 3. *Aviculopecten cf. coxanus.*
FIG. 4. *Pseudomonotis radialis* Meek.
FIG. 5. Undetermined.
FIG. 6. Undetermined.
FIGS. 7, 8. *Rhynchonella osagensis* Swallow. Two views.
FIG. 9. *Pleurotomaria cf. subdecussata* Geinitz.
FIG. 10. *Pleurotomaria marcouiana* Geinitz.
FIG. 11. *Rhynchonella* sp. Two views. (*cf. R. osagensis* Swallow).

FIG. 12. *Terebratula ?* sp. Two views.

FIG. 13. *Zaphrentis* sp.

FIG. 14. *Productus cora* D'Orb.

FIG. 15. Portion of the whorl of *Euomphalus* sp.? All the above are from shale number III of the Tularosa section.

FIG. 16. *Bakevellia parva* Meek and Hayden. From base of section near adobe smelter east of Sandia Mountains at the base of the Permian.

FIGS. 17, 18, 19. Undetermined gasteropods from the base of the Tularosa section.

FIG. 20. *Orthoceras* sp. Base of Tularosa section.

FIG. 20 *bis*. (Lower left corner) *Edmondia* sp. Same place as the above.

FIGS. 21, 22, 23. *Meekella striatocostata* Cox. From No. 3, Tularosa section.

FIG. 24. *Myalina permiana*, base of Tularosa section.

FIG. 25. *Bellerophon montfortianis* Norwood and Pratten. Base of section at adobe smelter.

FIGS. 26, 27. *Pleurophorus subcuneatus* Meek and Hayden. Same as the above.

FIG. 28. *Sedgwikia topekaensis* Shum. Shales below upper layers at Tularosa.

PLATE III.

FIG. 1. *Aviculopecten occidentalis* Shum. Left valve.

FIG. 2. *Aviculopecten occidentalis* Shum. Right valve.

FIG. 3. *Pseudomonotis hawni* Meek and Hayden. This and the above from the lowest level of the Tularosa section.

FIG. 4. *Myalina perattenuata* Meek and Hayden. Adobe smelter east of Sandias.

FIG. 5. *Myalina swallovi* Shum. Upper Carboniferous, Sandia Mountains.

FIG. 6. *Discina convexa* Shumard. As above.

FIG. 7. *Gervillia longa* Geinitz. As above.

FIG. 8. *Chonetes granulifera* Owen. As above.

FIGS. 9, 10. Unidentified gasteropod. As above.

FIG. 11. *Myalina ?* Permo-Carboniferous east side of Sandia Mountains.

FIG. 12. *Edmondia* sp. Base of Permian, adobe smelter.

FIG. 13. *Edmondia aspinwalensis* Meek. Permo-Carboniferous. Jemez Spring.

FIG. 14. Unidentified gasteropod. Upper Carboniferous.

Plate I

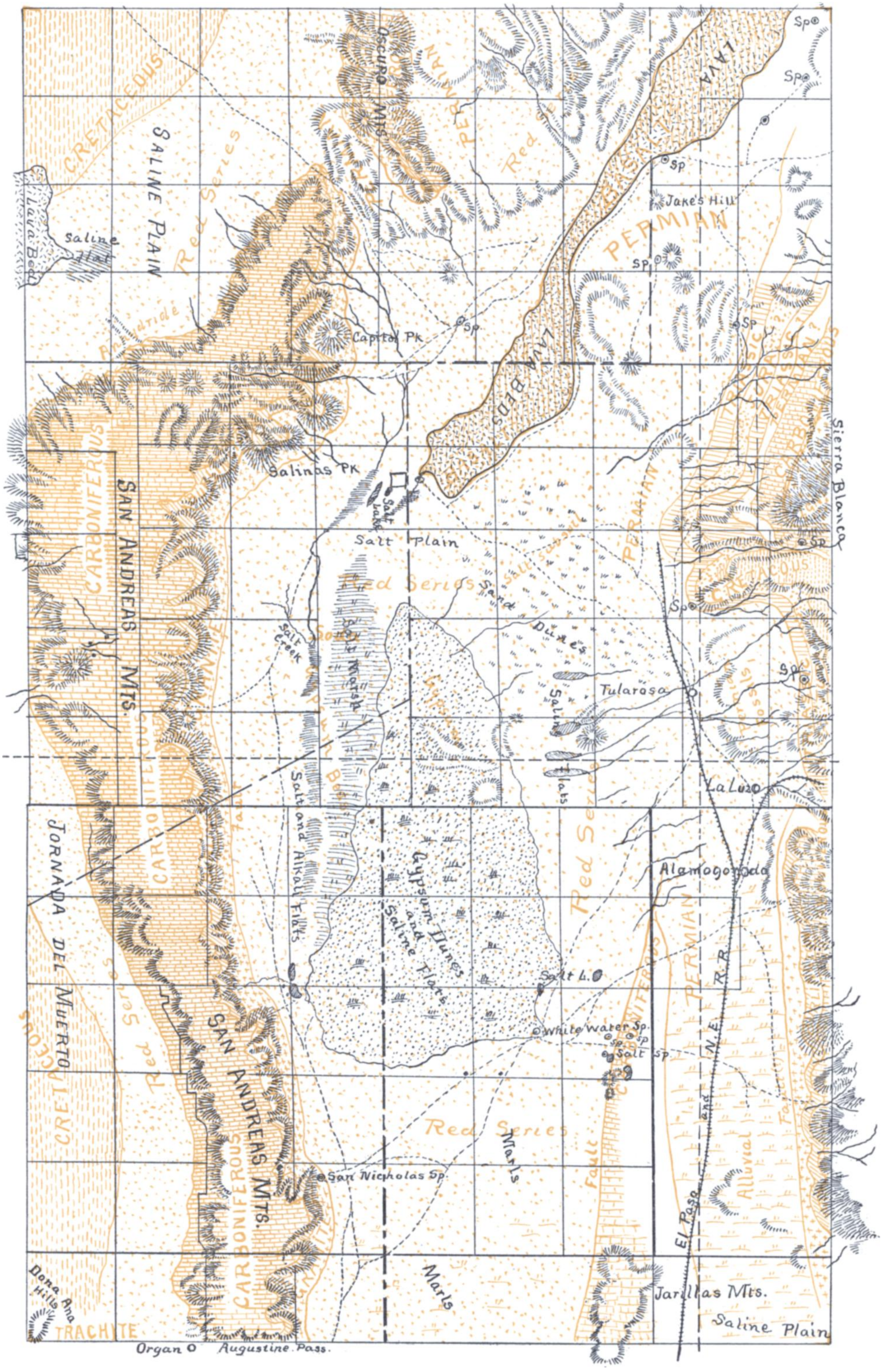
CRETACEOUS
SALINE PLAIN
Red Series
Lava Bed
Saline Flat
OSCURO MTS
PERMIAN
Red Series
LAVA
Sp
Jake's Hill
PERMIAN
Capitol Pk
LAVA BEDS
Salinas Pk
Salt Lake
Salt Plain
CARBONIFEROUS
SAN ANDREAS MTS.
Red Series
Sand Dunes
Salt Creek
Salt Marsh
Tularosa
Saline Flats
Sierra Blanca
CRETACEOUS
La Luz
JORNADA DEL MUERTO
Salt and Alkali Flats
Gypsum Dunes and Saline Flats
Alamogordo
Red Series
PERMIAN
Salt L.
White Water Sp.
Salt Sp.
CRETACEOUS
SAN ANDREAS MTS.
CARBONIFEROUS
Red Series
Marls
San Nicholas Sp.
Fault
El Paso and N.E. R.R.
Alluvial
Marls
Jarillas Mts.
Saline Plain
Dona Ana Hills
TRACHYTE
Organ
Augustine Pass.

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Plate II

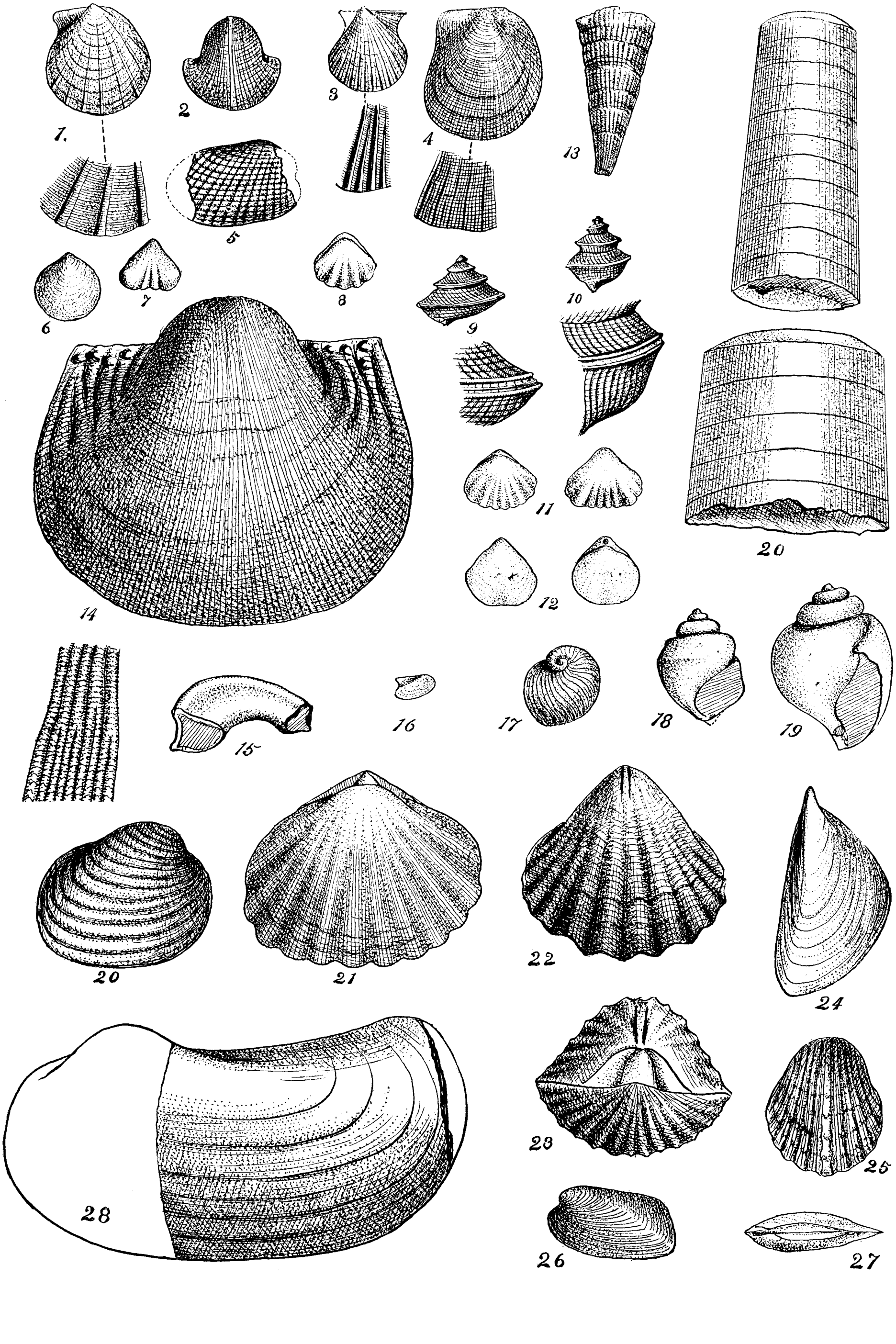

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Plate III