NACIMIENTO MOUNTAINS–HISTORY AND RELATION TO THE SAN JUAN BASIN

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The present San Juan Basin, a Laramide structural feature, has as its eastern boundary the Nacimiento and San Pedro Mountains,* an uplift some 45 miles in length and about 15 miles wide, with a fault of several thousand feet displacement marking the division between uplift and basin. The general Nacimiento-San Pedro Mountain area was uplifted during parts of the Paleozoic; this ancestral positive feature is referred to as the Peñasco axis or highland. The present expression of the Nocimiento-San Pedro Mountains had its beginning during the Laramide revolution.

These mountains have been mapped by Wood and Northrop (1946). The complex geologic history of the area is summarized briefly in this paper; more detailed discussions of parts of this history can be found in the cited references.

PRECAMBRIAN

During Precambrian time the area under discussion lay in the eastern part of a great, subsiding trough, the center of which received tens of thousands of feet of sediments. These rocks have been metamorphosed, and with the ancient granites, have been intruded by younger granites.

CAMBRIAN

The nearest known occurrence of Cambrian rocks is near the northwest corner of New Mexico, and while it is assumed that almost all of northern New Mexico was positive during the Cambrian period, there is a possibility that there was some deposition and subsequent erosion.

ORDOVICIAN AND SILURIAN

It seems likely that during these periods there was no deposition of sediments in northern New Mexico.

DEVONIAN

No Devonian rocks are known in the Nacimiento Mountain area, but their occurrence to the northwest in outcrop and subsurface makes it seem possible that a Devonian seaway or estuary may have extended across the area.

MISSISSIPPIAN

A middle Mississipian inundation of the Nacimiento area occurred as seas encroached from the south, and possibly from the northwest, but later Mississippian erosion occurred after the seas withdrew, and the limestones that had been deposited were largely removed, with the remnants being subjected to solution. Where these remnants are found (Arroyo Peñasco formation of Armstrong, 1955), the limestones contain fossils of mid-Mississippian age, and overlie a thin clastic member, barren of fossils, which in turn lies upon weathered Precambrian rocks. (Armstrong, 1955). The Arroyo Peñasco remnants are preserved in synclines or downfaulted blocks (Fitzsimmons et al, 1956), as late Mississippian or very early Pennsylvanian folding and faulting of the Peñasco area occurred.

PENNSYLVANIAN

In early Pennsylvanian time, another marine transgression covered at least parts of the Peñasco area, depositing arkose, sandstone, shale, and thin limestone (similar in part to the Molas formation of Colorado) upon the weathered Precambrian surfaces and the eroded remnants of Mississippian strata. The Pennsylvanian rocks are correlated with the upper clastic member of the Sandia formation (Wood and Northrop, 1946); they are deeply channeled and truncated in many places where overlain by the Madera formation.

As the Ancestral Rocky Mountains rose in southwestern Colorado, uplifts also took place to the east and northeast of the Peñasco area. Marine cherty limestones and shales of the lower limestone member of the Madera formation of middle Pennsylvanian age were deposited in a widespread sea. These rocks are present in the southern part of the Nacimiento Mountains. but are missing at San Pedro Mountain to the north, where only the upper arkosic member of the Madera formation rests on the Precambrian. On the west flank of San Pedro Mountain, no Pennsylvanian sediments are found and Permian beds lie on the Precambrian (Wood and Northrop, 1946), perhaps because this part of the Peñasco axis was positive throughout Pennsylvanian time.

The upper arkosic member of the Madera formation is middle to late Pennsylvanian in age, and consists of limestone and shale interbedded with arkose derived from the rising Ancestral Rockies. The seas in which the sediments of the Madera formation were deposited were open to the south, southeast, and northwest. At Guadalupe Box in the southern part of the Nacimiento Mountains, there are nearly 1000 feet of Pennsylvanian strata present. (Northrop, 1950).

PERMIAN

Late in Pennsylvanian or early in Permian time, the increasing supply of clastics from the active Ancestral Rockies probably caused the seas to withdraw from the area. Conditions of fluviatile, floodplain, deltaic, and piedmont sedimentation prevailed as the Abo and the lower part of the Cutler formations (which integrade near Señorita Canyon, southeast of Cuba, New Mexico) were deposited (Northrop, 1950). The lower part of the Cutler in this area is

*These San Pedro Mountains are not to be confused with the mountains of the same name that lie some 12 miles east of the north end of the Sandia Mountains.

probably late Pennsylvanian in age, for the Cutler intertongues with uppermost Madera strata (Wood and Northrop, 1946).

The Cutler formation consists mainly of red and brown arkosic sandstones and shales, which thicken northward into Colorado. The Abo formation is of similar lithology but is often finer grained, and extends southward from the Cutler boundary near Senorita canyon. Lower Cutler is probably older than lower Abo (Romer, 1950).

At the end of early Permian time, the Ancestral Rocky orogeny had slowed, but epeirogenic movement started to downwarp the Nacimiento Mountain and San Juan Basin area so that the Permian seas encroached on the region from the south. A basal cross-bedded sandstone of the Yeso formation, the Meseta Blanca member, overlies the Abo in the southern port of the Nacimiento area, and intertongues with the Abo further north. Still further north it tongues into the Cutler formation near Senorita pass (Northrop, 1950) . The Meseta Blanca is 350 to 400 feet thick in the southern Nacimiento Mountains. In the same area, the upper member of the Yeso is the San Ysidro sandstone (90 to 160 feet thick), composed of dark red to light orange, thin to medium-bedded sandstones and siltstones that grade into limestones and evaporites to the south. The San Ysidro member seems to be approximately equivalent to the Los Vallos member of the Yeso on the Lucero uplift (Kelley and Wood, 1946) . The Glorieta sandstone overlies the Yeso in the Nacimiento region. It consists of 70 to 105 feet of buff to white sandstone (Northrop, 1950) and is recognizable as far north as San Ysidro (Read, 1951). The Glorieta sandstone is overlain in the southern Nacimiento Mountains by a thin (ten feet at most) limestone which is thought to represent the northernmost extent of the San Andres limestone. The upper sandstone member of the San Andres in the southern Nacimiento region is 30 to 45 feet thick (Northrop, 1950). The most northerly position of the strand line of mid-Permian time, when the Yeso, Glorieta, and San Andres formations were deposited in this area, was somewhere between the San Pedro and Nacimiento Mountains (Read, 1951). South of this shifting strand line the delta and floodplain deposits of the Cutler grade into the beach and bar tangentially cross-bedded deposits of the Meseta Blanca and Glorieta sandstones (Read, 1951).

A period of erosion ensued before upper Triassic deposition, as a general uplift of the Nacimiento region caused beveling of the San Andres and Glorieta to the south, the Yeso farther north, and the Cutler in the San Pedro Mountains.

TRIASSIC

In early Triassic time, the Moenkopi formation was deposited in Arizona; its eastward extent is unknown but no recognizable equivalent is present in the Nacimiento area, nor are mid-Triassic sediments found in the region. In late Triassic time, the Nacimiento area again began receiving sediments as the uplifts to the east and northeast were rejuvenated. The Agua Zarca sandstone (90 to 400? feet thick) thins northward through the Nacimiento area. It is overlain by the Salitral shale tongue (0 to 105 feet thick), which in turn is overlain in the northern part by the southward-thinning Poleo sandstone (0-105 feet thick). These are members of the Chinle formation, overlain by the uppermost member, a main shale body (235 to 953 feet thick) containing beds of siltstone, sandstone, and conglomerate (Northrop, 1950).

Apparently separate uplifts to the southeast and northeast of the Nacimeinto area supplied sediments for the conglomeratic Agua Zarca and Poleo sandstones. The Upper Chinle shale and the underlying Salitral tongue were the products of fluviatile, floodplain, and swampy conditions upon a vast, west-sloping plain, with the sea far to the west in Nevada. An upland of low relief apparently prevented Chinle deposition from extending southward from central New Mexico; this positive element has been termed the Navajo Highland by Smith (1951), and the Zuni Highland by Rapaport (1952).

JURASSIC

Regional upwarping in Early Jurassic time resulted in desert conditions in northern Arizona while the Nacimiento region probably suffered erosion. Apparently the floodplain, lake, and stream type of deposition of the upper Triassic were resumed in middle Jurassic to form the Carmel deposits. In the Nacimiento region, the Carmel formation consists of red and brown shales, siltstones, and sandstones. They lie upon the Chinle with little evidence of a hiatus. After Carmel deposition, broad emergence caused desert conditions to prevail while the massive to cross-bedded eolian Entrada sandstone, 150 to 300 feet thick in the Nacimiento region, blanketed a desert that reached far into Arizona, and into southern Colorado and Utah.

Lying upon the Entrada is the Todilto formation, consisting of limestone and white gypsum which is 75 to 130 feet thick in the Nacimiento area (Wood and Northrop, 1946). Aparently the Todilto was formed as encroaching marine or lacustrine conditions extended over most of northwestern New Mexico and into the extreme eastern part of Arizona.

The thinned edge of the Summerville formation, which overlies the Todilto, has been recognized in the southern end of the Nacimiento Mountains (Freeman and Hilpert, 1956) but the Bluff sandstone, derived from sources far to the northwest, is absent, having thinned to extinction somewere west of the Nacimientos. The Summerville thickens to the west, where it is separated from the lithologically similar Recapture shale of the Morrison by the Bluff sandstone. Freeman and Hilpert (1956) found the Summerville overlain by the Recapture shale in the southern Nacimiento Mountains.

The Morrison formation was distributed across broad

floodplains as fluviatile deposits in the late Jurassic, with sources far to the west. In the southern Nacimiento area, the following members of the Morrison have been measured (Freeman and Hilpert, 1956):

Recapture mbr.: predominantly red and orange sandstones and claystones, 276 feet thick.

Westwater Canyon mbr.: predominantly yellow, orange, and white sandstones, 171 feet thick.

Brushy Basin mbr.: Multicolored claystones, 105 feet thick.

The Morrison is dealt with in detail by Craig (1955) and by McKee (1956).

CRETACEOUS

During early Cretaceous time there was erosion of Jurassic rocks in the Nacimiento region and throughout much of northern New Mexico. By late Cretaceous time probably the entire state was submerged as the seas, which had been confined to southern New Mexico in the early Cretaceous, covered New Mexico and extended far to the north, depositing the sandstones and basal conglomerates of the Dakota formation. After a period of fluctuating shorelines and swamps that characterize the upper part of the Dakota, the Cretaceous seaway subsided and the marine shales of the Mancos were deposited. The Mancos reaches a thickness of 2200 feet in the northern part of the San Juan Basin.

To the west and southwest of the present San Juan Basin, uplifts contributed debris that was deposited in coastal swamps, in deltas, and along beaches as the Mesaverde formation. As the strand line alternately advanced and retreated, the Mesaverde and Mancos intertongued many times. The Mesaverde is about 1800 feet thick in the Gallup area, despite the erosion of an unknown but substantial amount of its upper beds (Beaumont, Dane, and Sears, 1956). In the Nacimiento area, the Mesaverde group is about 2000 feet thick near La Ventana, but thins to the north.

The Mesaverde is overlain by the marine Lewis shale which is 2200 feet thick in the northern San Juan Basin but thins to 100 feet or less at Chacra Mesa, west of the Nacimiento area.

As the late Cretaceous seas withdrew to the northeast, the regressive Pictured Cliffs sandstone was deposited upon the Lewis shale. Then the continental shales, sands, and coals of the Fruitland formation were deposited, thicker (probably up to 500 feet) nearer their source area in northwestern New Mexico and southwestern Colorado, thinning and intergrading with lobes of the Pictured Cliffs sandstone to the east (Silver, 1950).

Fluviatile sediments of the Kirtland formation were deposited in the San Juan Basin area from sources to the west and northwest, reaching thicknesses of 1200 feet in the western San Juan Basin, but diminished rapidly to the east.

At the beginning of the Laramide orogeny, great thicknesses of arkosic sands and shales were deposited in the San Juan Basin region. These include the McDermott and Animas formations in the north and the thinner, cross-bedded, conglomerate Ojo Alamo sandstone to the south and in the Nacimiento region. Faunas of the Kirtland, Fruitland, and Ojo Alamo of New Mexico are very closely related (Colbert, 1950).

TERTIARY

Paleocene

As Laramide orogeny continued, the Animas, Nacimiento, and San Jose formations were deposited as continental piedmont and fluviatile sediments deposited on a broad, south-sloping plain rather than in a subsiding basin. The thicknesses of these deposits are the result of the tremendous uplifts to the north and northwest.

Somber-colored banded clays and sandstones of the Nacimiento formation (400 to 800 feet thick) were deposited disconformably upon the Ojo Alamo sandstone (Simpson, 1950). To the north, the Nacimiento grades into the upper part of the Animas which is shown by scant fossil evidence to be Paleocene in age, while the middle and lower parts of the Animas contain dinosaurs in Colorado. The Nacimiento formation has been divided into two faunal zones, based on vertebrate fossils—the early (Puercan) and middle (Torrejonian) Paleocene. These units are lithologically indistinguishable (Simpson, 1950).

In Colorado, the San Jose lies disconformably on the Animas. There the San Jose ranges from late Paleocene to early Eocene in age, whereas in the Nacimiento Mountain area, it is probably all early Eocene, with the late Paleocene represented by a hiatus at the San Jose-Nacimiento disconformity (Simpson, 1950).

Eocene

"Uplift and folding of the Nacimiento-San Pedro axis may have begun in late Paleocene time and culminated in the major thrusting during late Eocene (post-San Jose) time", according to Northrup (1950), because the San Jose formation has been uplifted along the western flank of San Pedro Mountain.

The San Jose formation is some 2000 feet thick in the extreme southern part of Colorado, but thins to 1000 feet and less in the Nacimiento area, where it consists of white, copper, and buff-colored, cross-bedded sandstones and conglomerates, and varicolored, banded, clays and silts (Simpson, 1950). "Except for Quaternary (and possibly some latest Tertiary) unconsolidated pediment, terrace, and valley sediments, the San Jose is the youngest formation in the San Juan Basin." (Simpson, 1950).

Oligocene to Present

"Movement along the major zone of thrusting (at the eastern edge of the Nacimiento-San Pedro Mountains) may have continued intermittently during Oligocence time. Normal faulting of the Basin-and-Range type was probably inaugurated during the Miocene and may have continued

intermittently into Pliocene time", according to Northrop (1950).

The Jemez region, east of the Nacimiento Mountains, was the site of tremendous eruptions during Pleistocene time, when the Jemez caldera, or Valle Grande, was formed. Since then, volcanism has occurred intermittently in the region (Northrop, 1950). The Jemez caldera has a rim some 15 miles in diameter and a relief of 600 to 800 feet, so that it is one of the largest calderas in the world.

Pleistocene formations in the Nacimiento region are mostly rhyolitic to balsaltic flows and tuffs, pediment gravels, alluvium, and spring deposits (Northrop, 1950). Probably much of the late Tertiary volcanic material was distributed over the eastern part of the San Juan Basin, but has been removed by erosion. Thus it has been speculated that the uranium-bearing coals of the La Ventana (upper Cretaceous) formation just west of the Nacimiento Mountains have been enriched by the former presence of the Bandelier tuff (of probable Pleistocene age) overlying the La Ventana, with solution of the radioactive minerals from the tuff and absorption by the organic material in the La Ventana (Cannon, 1956).

As the volcanic activity of the later Cenozoic continued in southern Colorado and regions to the northeast of the Nacimiento area, vast uplifts elevated the entire region. Large scale erosion has taken place to the present.

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