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1983, pp. 193-196. https://doi.org/10.56577/FFC-34.193

in:

Socorro Region II, Chapin, C. E.; Callender, J. F.; [eds.], New Mexico Geological Society 34th Annual Fall Field Conference Guidebook, 344 p. https://doi.org/10.56577/FFC-34

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FOSSIL PLANTS FROM THE EARLY NEOGENE SOCORRO FLORA, CENTRAL NEW MEXICO

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INTRODUCTION

The Socorro flora occurs in the early Neogene Popotosa Formation near Socorro, New Mexico, and consists of impressions of juniper foliage and angiosperm leaflets and floral parts. The occurrence of this fossil assemblage was first reported by C. Burton (1971, unpub. student report for New Mexico Institute of Mining and Technology). The collection upon which the present study is based was made during 1980 and 1981 in conjunction with the author's work on Tertiary floras of the Rio Grande rift.

The flora is of particular paleobotanical interest because of the unusually small size of the preserved plant structures, and because of the presence of several reproductive parts. This paper discusses the geologic occurrence of the flora, illustrates some of the common fossil plants, and presents an interpretation of the paleoecology.

LOCATION, STRATIGRAPHY, AND AGE

The Socorro flora is located 6 km west of Socorro, New Mexico, in a ravine on the south side of Socorro Peak (fig. 1), in the NW'/4 SE'/4 SEV4 sec. 8, T3S, R1W. The fossils occur in a layer of light-gray siltstone to mudstone (weathering to a light-yellow, crumbly clay at the surface) that is underlain by sandstones and overlain by conglomerates and sandstones (fig. 2).

The flora occurs in the lower Popotosa Formation; this and related units of the Socorro Peak volcanic center have been described by Chamberlin (1980, 1981), Chapin and others (1978), and Chapin and Seager (1975). Deposition of the Popotosa Formation occurred in a broad, closed sedimentary basin that developed as a result of crustal extension associated with formation of the Rio Grande rift. Sediment accumulation in this basin graded from coalescing alluvial fans along the bordering uplifted areas into playa lakes along the basin floor, as evidenced by the intertonguing fanglomerate, piedmont-slope, fluvial, and playa deposits that comprise the Popotosa Formation. Chamberlin (1980) mapped the localized sedimentary sequence containing the fossil flora as the gray mudstone and siltstone facies of the lower Popotosa Formation. The close association of this facies with a gray conglomeratic sandstone facies representing distal alluvial-fan deposits suggests that the silty mudstones are basin-floor sediments deposited in small lakes or on alluvial flats.

The Popotosa basin persisted from about 27 m.y. ago to 7 m.y. ago. The Popotosa Formation unconformably buried the northernmost portion of the Socorro cauldron, which collapsed concomitant with eruption of the Hells Mesa Tuff 33 m.y. ago, just prior to initiation of the Rio Grande rift (Chapin and others, 1978). This was followed by the eruption of several regional ash-flow tuffs from other cauldrons in the area of the San Mateo and Magdalena Mountains; the South Canyon Tuff (about 26.7 m.y.; Osburn and Chapin, 1983) is the youngest of these regional ash-flow sheets. Basal deposits of the lower Popotosa Formation rest unconformably on the South Canyon Tuff and on rhyolites in the Water Canyon Mesa area (dated at about 20.5 m.y.; Osburn and Chapin, 1983). A period of magmatic inactivity existed in the Socorro area until renewed magmatism erupted rhyolitic domes and tuffs of the Socorro Peak Rhyolite onto the floor of the Popotosa basin between 12 and 7 m.y. ago.

The age of the Socorro flora is conservatively bracketed between the 26.7 m.y. old South Canyon Tuff and the oldest (11.9 m.y.) flows of the Socorro Peak Rhyolite, and is possibly younger than the 20.5 my. old rhyolites of Water Canyon Mesa (C. E. Chapin, 1983, oral commun.). The occurrence of the flora in a facies contemporaneous with the red mudflow facies of the Popotosa Formation suggests that it may represent a period between 20 and 15 m.y. (R. M. Chamberlin, 1983, written commun.). Thus, the Socorro flora is probably early or middle

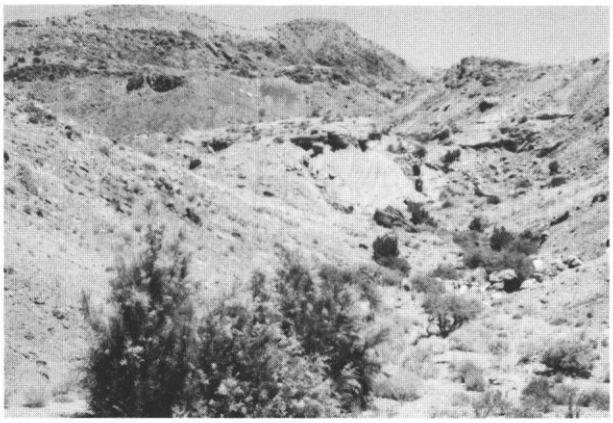

Figure 1. View north (toward Socorro Peak) along the arroyo leading to the fossil locality in the light-colored strata near the center of the photograph.

Figure 2. View of light-gray fossiliferous siltstone to mudstone strata of the lower Popotosa Formation at base at overhanging ledge of sandstones and conglomerates.

Miocene (early Neogene) in age, although it may be as old as late Oligocene (latest Paleogene).

Refinement of the age through biostratigraphic correlation of the Socorro flora is not yet possible because the assemblage is not sufficiently diverse and includes taxa that are unknown from other Tertiary floras. Other fossil leaf floras from the southern Rocky Mountain region are younger than about 15 my. and older than about 27 my.; the Socorro flora therefore probably represents a period previously unknown from paleofloras of this region.

FOSSIL PLANTS

The quality of preservation of the fossil plants is variable. Many of the specimens have excellently preserved venation, but some (particularly those with thick textures) show little more than leaf outlines and cannot be accurately identified. Several of the plant fossils are illustrated in Figure 3.

Juniperus (juniper) is known in the Socorro flora from foliage (fig. 3A—D) that is most similar to that of the living *J. osteosperma* (Utah juniper) and *J. caltfornica* (California juniper), and to the fossil foliage of *J. nevadensis* from middle Miocene floras in Nevada (Axelrod, 1940, 1956; Wolfe, 1964). These junipers share such features as decussate arrangement of the leaves, overlapping of the facial leaves, and a tendency for the leaves to be somewhat pointed. *Juniperus californicus* is characterized by the presence of many more glands than *J. osteosperma,* but the occasional presence of glands on some of the Socorro specimens is not a diagnostic feature since the lack of abundant glands may be due to factors of preservation. These living junipers are large shrubs to small trees that occur through a wide altitudinal range and occupy dry habitats that range from woodlands to scattered trees along arroyos and on alluvial fans.

Small leaflets of *Calliandra* (false mesquite) are the most common fossils in the Socorro flora. These represent a new species of *Calliandra* and will be described in a forthcoming paper (Meyer, in preparation). The leaflets measure 5 to 8 mm in length, yet the details of venation are frequently well preserved. Three specimens show attachment of the leaflets to the rachis of the leaf (fig. 3F—H). The Socorro *Calliandra* is most similar to the living C. *reticulata,* but also has affinities with C. *humilis.* These modern species of *Calliandra* are perennial herbs or low shrubs that grow on slopes or in dry conifer forests of Arizona and New Mexico.

A leaf specimen *(fig.* 3E) having a distinctive deltoid-hastate shape with a basal notch is similar to *Convolvulus* (morning glory), although the venation is poorly preserved. Additional specimens showing better preservation are -needed to verify this identification. The living representatives of *Con volvulus* are trailing or twining herbs that grow well on disturbed sites.

A single fragmentary leaflet (fig. 3M) is probably *Robinia* (locust). The living southwestern species of this genus, *R. neomexicana,* is a small tree that is usually found on moist sites and frequently forms thickets.

Flowers are rare as fossils, but one articulated specimen and several isolated flower parts have been found in the Socorro flora. The complete specimen (fig. 3N) has 6-parted symmetry, typical of the monocots, and individual petals and sepals that can be distinguished by their spatulate and lanceolate shapes, respectively.

PALEOECOLOGY

The taxonomic composition of the Socorro flora indicates that the living representatives of these plants are adapted to dry climatic conditions. The lack of riparian deciduous plants further suggests that the watercourses around the Popotosa basin were only intermittently wet. In addition to the taxonomic indications of climate, some of the plants have physiognomic features that are useful in formulating paleoecological interpretations. For example, the indeterminate specimen illustrated in Figure 3P possesses a thick texture (probably the reason for its indistinct venation) and an entire, revolute margin. Such features are typically drought adaptations and indicate aridity. Although climatically xeric conditions appear to be indicated, physiological drought may also have been a factor if saline or alkaline conditions existed in the Popotosa basin.

The Socorro flora probably represents a type of vegetation similar to the *"Juniperus* series" described by Layser and Schubert (1979), characterized by open stands of juniper and a usual absence of other conifers. The individual juniper trees may be very scattered in this open woodland vegetation. In other instances, however, juniper does not form a widespread woodland but rather is restricted to specific sites, such as on alluvial fans or in arroyos. It is presently impossible to determine whether the Socorro flora represents a well-developed juniper woodland or a more restricted occurrence of juniper trees on the alluvial fans surrounding the Popotosa basin. Based upon the modern distribution of this kind of vegetation, the mean annual temperature of the Socorro flora was about 12° -± 2°C and the mean annual range of temperature (the difference between the warmest and coldest mean monthly temperatures) about 22° -± 3°C. The mean annual precipitation was approximately 25 to 40 cm.

Estimating the paleoaltitude of the Socorro flora is complicated by the lack of a well-defined age, the difficulty in estimating paleotemperatures, and the location of the flora in the continental interior. Using sea-level temperatures from Pacific Coast paleofloras and compensating for the probable effects of continentality, the available data suggest a paleoaltitude of perhaps 1100± 300 m, or, at most, less than the present altitude of 1830 m at the fossil locality. Axelrod and Bailey (1976) estimate that there has been about 1100 m of epeiric uplift since the middle Miocene based upon fossil palm in the Skull Ridge Member of the Tesuque Formation in northern New Mexico. Although the Socorro flora indicates uplift of about 700 ± 300 m, the results are generally compatible with those obtained for the Skull Ridge, particularly considering that the areas are separated by more than 200 km.

Although the very dry character of the Socorro flora is not as pronounced in other Tertiary floras of the region, these other floras nevertheless show that a trend toward seasonal drought began in the Rocky Mountain area during the middle Eocene. Most of these floras occur north of the Socorro area in the central and southern Rocky Mountain region from Wyoming to central New Mexico. The earlier Eocene floras were indicative of humid subtropical conditions and show relationships to the modern floras of eastern Asia, but by the later Eocene the southern Rocky Mountain floras indicate subtropical and seasonably dry conditions similar to those of southern Mexico and Central America (Leopold and MacGinitie, 1972). The flora of the early Oligocene (late Eocene of Armentrout, 1981, and of Wolfe, 1981) is similar to the present upland flora of northeastern Mexico, and by the late Oligocene and Miocene, the fossil floras of this region had essentially developed their modern Rocky Mountain aspect. This more modern character is shown by fossil floras such as Creede (a mixed conifer forest from southwestern Colorado) and Hillsboro (a subalpine forest from south-central New Mexico). The Socorro flora also has a basically modern aspect, but is significant in that it represents a type of vegetation previously unrecorded by the fossil floras of this region.

SUMMARY

The Socorro flora is not similar to any other known fossil leaf assemblage; most striking is the consistently small size of its components. It is noteworthy among Rocky Mountain floras because of the very dry ecological conditions that it indicates and the period of time that it

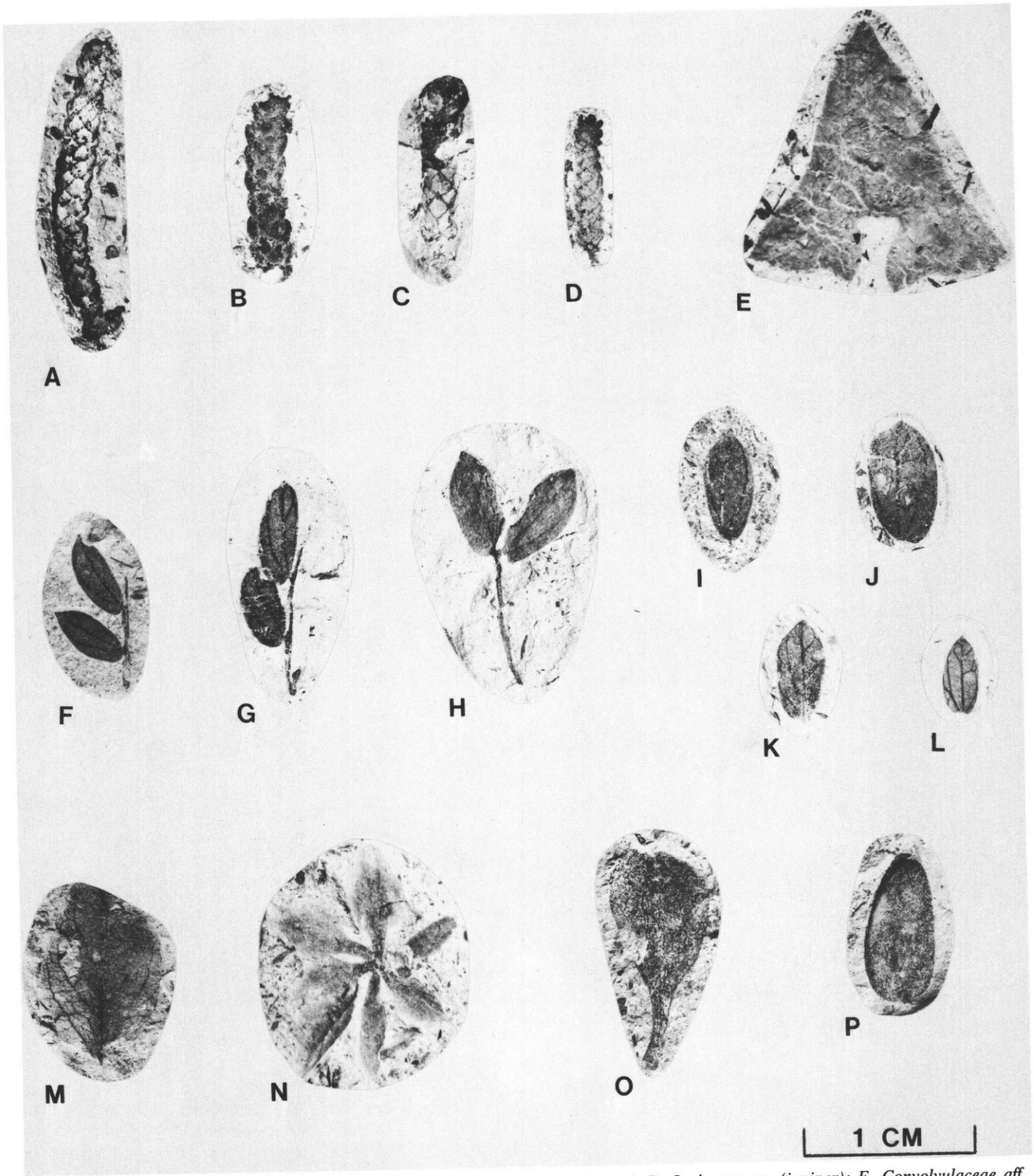

Figure 3. Fossil plants from the Socorro flora (enlarged approximately 3×). A–D. Juniperus *sp. (juniper); E. Convolvulaceae aff.* Convolvulus *sp. (morning glory); F–L. Calliandra sp. (false mesquite); M. Leguminosae cf.* Robinia *sp. (locust); N. monocot flower; O. flower petal; P. indeterminate leaf or leaflet.*

represents. Better precision in the age of the flora is critical to improving the utility of the assemblage. More extensive collecting is needed and will undoubtedly produce new taxa that will help refine the interpretations presented by this report.

ACKNOWLEDGMENTS

The author is grateful to R. M. Chamberlin and C. E. Chapin of the New Mexico Bureau of Mines and Mineral Resources for their help in interpreting geologic problems, to H. E. Schorn and S. W. Edwards of the University of California at Berkeley and J. A. Wolfe of the U.S. Geological Survey for help in identification of the fossil plants, and to K. Sakamoto of the U.S. Geological Survey for photography of the fossils illustrated.

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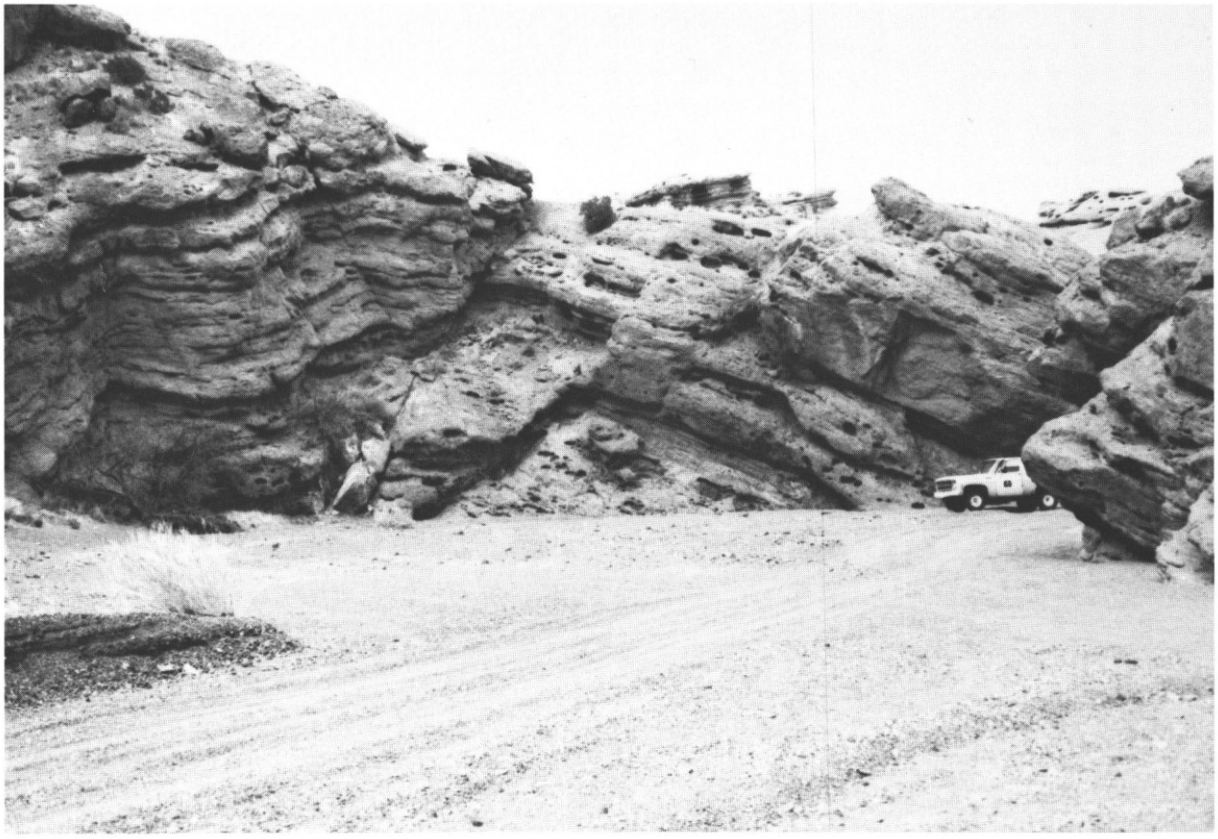

Maze of tilted and eroded Popotosa fanglomerates in San Lorenzo Canyon. Photo by R. M. Chamberlin.