URANIUM POTENTIAL OF THE DATIL MOUNTAINS-PIETOWN AREA, CATRON COUNTY, NEW MEXICO

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by
Richard M. Chamberlin, Ph.D.
Economic Geologist

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ABSTRACT

The Datil Mountains-Pietown area lies along the southern margin of the Colorado Plateau and the northern eroded margin of the Datil-Mogollon volcanic field. Cretaceous and Cenozoic strata, which dip gently southward under the area, are cut by northeast- and northwest-trending faults and folds related to Laramide compression and late Cenozoic extension.

Several small uranium deposits in the Red Basin mine area occur along the base of an exhumed zone of lateritic weathering ("C" horizon of a paleosol), which is as much as 150 feet thick. The paleosol was developed on, and within, carbon-rich sandstones and shales of the Crevasse Canyon Formation (Late Cretaceous) in Paleocene (?) time. Tropical or subtropical weathering leached trace concentrations of uranium (10-25 ppm) from the Crevasse Canyon shales in the upper vadose zone of the weathering profile. Uranium was redeposited below the water table at redox boundaries (analogous to soil gleys?) that formed in a zone of oxidizing and actively flowing groundwater about 20-50 feet thick. Combined effects of composite fluvial aquifers, folding of beds, and paleotopography produced a complex array of small roll fronts, but the overall hydrologic gradient appears to have been easterly.

In Eocene time, the uranium-bearing weathered zone was locally scoured by southeast-trending paleovalleys, which were then filled and buried by as much as 1900 feet of fluvial and interfluvial red-beds of the Baca Formation. Some uranium may have been flushed from the weathered zone by shallow groundwater flow in early Baca time, but most of the uranium deposits were preserved

during Eocene to Miocene time by burial beneath the Baca Formation and as much as 2000-3000 feet of volcanic rocks of the Datil-Mogollon field.

In late Cenozoic time, southward tilting, uplift and erosion has exposed the post-Crevasse Canyon pre-Baca paleosol along the north flank of the Datil Mountains. Numerous fossil roll fronts, which have been largely leached of uranium in Quaternary time, are exposed along the truncated northern edge of the paleosol. Some fossil roll fronts appear to be as much as a mile long, 40 feet high and 30 (?) feet wide. Unleached, but otherwise similar, roll-front deposits should be preserved in the down-dip projection of the paleosol where it lies below the present water table. Extrapolation of published data on the Red Basin reserve area suggests that at least 15 million pounds, and as much as 30-45 million pounds, of U_3O_8 should be present under a relatively unexplored area of about 80 square miles where the pre-Baca paleosol is at a depth of less than 1000 feet.

Outcrop belts of conglomeratic sandstone in the Baca Formation, which appear to represent braided channel complexes, are locally bleached and contain epigenetic uranium occurrences that pseudomorph syngenetic concentrations (placers) of iron oxides. The Baca sandstones have favorable aquifer characteristics, but their subsurface capacity to act as a trap for uranium deposits is presently unknown.

ACKNOWLEDGMENTS

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Chuck Chapin, John Hawley and Steve Hook reviewed the manuscript and made many valuable suggestions, which significantly improved the final report. The extra effort of Sue Ness, who typed several revisions of the manuscript, is greatly appreciated. Lois Devlin also assisted with the typing. Finally, I especially thank Dr. Frank Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, for his unwavering encouragement during all phases of this project.

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

The purpose of this report is to present a brief analysis of the uranium potential of the Datil Mountains-Pietown area. This analysis is based on reconnaissance geologic mapping (1:100,000) and detailed geologic mapping (1:24,000) in some mineralized areas. The results of this mapping are summarized on a generalized geologic map of the area (1:250,000; see fig. 1, p. 7). Observation made during this mapping project provide constraints on the age and origin of known uranium deposits (Red Basin area), which are then used in the construction of a conceptual model describing the genesis of these deposits. This genetic model is then applied to determine the areas most favorable for uranium exploration in the Datil Mountains-Pietown area. The substantive nature of the genetic model also permits its use in delineating other areas in New Mexico where similar uranium deposits may be found. This work was done as part of the New Mexico Bureau of Mines and Mineral Resources' "Red Flats Project", which was begun on May 1, 1980. A relatively detailed reconnaissance map of the Datil Mountains-Pietown area (1:100,000) will be presented in a separate open-file report.

The Datil Mountains-Pietown area (380 mi^2) is located in the northeastern corner of Catron County in west-central New Mexico. The village of Pietown lies in the southwest corner of the area along U.S. Highway 60. Most of the area is accessible via graded state roads, Cibola National Forest roads, and some unimproved roads that require a four-wheel drive vehicle.

In physiographic terms, the area lies along the southern margin of the Colorado Plateau, along the eroded northern margin of the Datil-Mogollon volcanic field, and is irregularly transected by the continental divide. Alamocita Creek, on the north flank of the Datil Mountains, represents the headwaters of a major tributary (the Rio Salado) of the Rio Grande.

Since the early 1950's, uranium has been known to occur in an east-trending belt of Cretaceous and Tertiary sandstones that are exposed along the southern margin of the Colorado Plateau in west-central New Mexico. One of the most promising early discoveries was the Red Basin mine (Bachman and others, 1957), which is located on the northern toe of the Datil Mountains. The Atomic Energy Commission originally estimated probable reserves of 30,000 pounds of U_3O_8 at a cutoff of 0.15 percent for the Red Basin deposit (Collins, 1957).

Since 1970, Gulf Mineral Resources has held several claim blocks and done considerable shallow drilling in the Red Basin area. Rumors of discoveries by Gulf led to an extensive land play in the Datil Mountains area by the mid-1970's. In 1978, exploration was stimulated in the Pietown area by a report of anomalous well waters containing as much as 680 ppb uranium (Sharp and others, 1978).

Numerous reports discussing the geology of the Datil and Red Basin areas have described (or alluded to) a "transition zone" between the Baca Formation (Eocene) and the underlying late Cretaceous rocks of the Crevasse Canyon Formation; the "transition zone" is considered to be a favorable horizon for uranium deposits (Bachman and others, 1957; Snyder, 1971; Johnson, 1978; Chapin and others, 1979; May and others, 1980; Pierson and others, 1981). Key outcrops were found during this project that provide constraints on the age, and thus the origin, of the "transition zone". The geometry, internal character and contact relationships of the "transition zone" are best explained if it is interpreted as the thick subsolum of a lateritic soil that was developed on and within the Crevasse Canyon Formation in a tropical or subtropical climate prior to deposition of the Baca Formation. The recognition of this lateritic paleosol is the most significant result of this project, since this zone of intense leaching, groundwater alteration, and groundwater mineralization should extend far beyond the Datil area as a target for uranium exploration. The Red Basin deposits are simply another variation of uranium deposits associated with unconformities (Langford, 1977; Chamberlin, 1981).

GEOLOGIC SETTING

The Datil Mountains-Pietown area is located on the southern margin of the Colorado Plateau, the eroded northern margin of the Datil-Mogollon volcanic field, and on the northern flank of the San Augustin arm of the Rio Grande rift (Chapin, 1971). From west to east, the Datil Mountains, northern Gallinas Mountains, and northern Bear Mountains, form a stepped pattern (en echelon?) of west-northwest trending volcanic ranges (Dane and Bachman, 1965). These parallel segments of the ranges exhibit progressively increasing southerly dips as they approach the extensional axis of the Rio Grande rift. Thus, the gentle south-southwest tilt of Cretaceous and Tertiary strata that underly the Datil Mountains may be attributed to relatively minor extension and sagging of the Colorado Plateau margin in late Cenozoic time.

Surface structures in the Datil Mountains-Pietown area (fig. 1, p. 7) are related to Laramide compression (late Cretaceous to late Eocene) and to late Cenozoic extension (late Oligocene to present). The oldest structures are broad and low amplitude anticlines and synclines that deform the Crevasse Canyon Formation in the northeast portion of the map area. These folds appear to be part of an echelon fold belt that continues about 40 miles to the north of the map area (Wengerd, 1959). North of the map area, near Cebolleta Mesa, northwest-trending folds appear to be dominant. Within the Datil Mountains area, southwest-trending folds appear to be dominant. Locally, these southwesterly plunging folds are truncated or buried by an erosional unconformity at the base of the Baca Formation. Northeast-trending high-angle faults, which cut Cretaceous rocks in the area northwest of Alamocita Creek, appear to be related to these early Laramide folds (fig. 1). These buried early Laramide folds and faults probably formed important structural controls on uranium deposits that were formed in the post-Crevasse Canyon pre-Baca paleosol.

The Red Lake and Hickman fault zones may represent Laramide reverse faults that have been reactivated as late Cenozoic normal faults. As shown by Wengerd (1959, fig. 4), the Red Lake and Hickman fault zones (systems) form the margins of a broad north-northeast trending "synclinal horst", which plunges under the Datil Mountains at the south end of the horst. The north end of this synclinal horst merges in some unknown way with the Laramide Acoma sag, which plunges northward into the San Juan Basin. If the Red Lake and Hickman structures are of Laramide ancestry, then the Baca Formation could reasonably be expected to thin abruptly to the east and west of this synclinal horst block. Composite measured sections of Johnson (1978) indicate that the Baca Formation is thickest in the Datil Mountains area, and thins markedly to the east and west. The patterns of Laramide structures in the Datil Mountains-Pietown area are similar to those described in the Rio Puerco fault zone of north-central New Mexico (Slack and Campbell, 1976).

Long, northwest-trending mafic dikes (basaltic andesite?) that cut across the map area mark the onset of crustal extension in late Oligocene time. The dike system that passes west of Pietown was emplaced about 27.7 m.y. ago (Laughlin and others, 1979). Fractures occupied by these dikes show no apparent displacement.

Younger northeast and north-northwest trending normal faults commonly exhibit major displacements. The composite stratigraphic throw on the Red Lake fault zone may be several thousand feet and the Hickman fault zone may have a late Tertiary displacement of as much as 1000 feet. These fault zones decrease in displacement toward the north. Locally the Hickman fault zone has the character of an asymmetric anticlinal fold, which looks like a giant kink band in cross section. Minor faults that have displacements of 50 feet or less are not shown on the generalized geologic map (fig. 1).

The major stratigraphic units of the Datil Mountains-Pietown area (Table 1) record a history of: 1) fluvial and paludal sedimentation on a highly vegetated coastal plain in a tropical or subtropical climate (Crevasse Canyon Formation), 2) development of a thick lateritic soil on the coastal-plain deposits as the sea withdrew and the water table dropped--uranium deposits formed in an actively flowing portion of the saturated zone at base of the weathering profile (Post-Crevasse Canyon Pre-Baca Paleosol), 3) fluvial and mudflat sedimentation in a poorly vegetated Laramide basin in a hot-semiarid climate (Baca Formation), 4) voluminous intermediate and rhyolitic volcanic eruptions from volcanic centers and calderas to the south and east of the map area (rocks of the Datil-Mogollon volcanic field), 5) the onset of crustal extension (mafic dikes), 6) alluvial-fan and braided-stream sedimentation (associated with epeirogenic uplift) with northwestward transport away from the upturned margin of the volcanic field (late Tertiary conglomerates) and 7) local erosion and sedimentation contemporaneous with uplift and subsidence of fault blocks to form the present landscape (Quaternary alluvium).

TABLE 1. Stratigraphic and rock units of the Datil Mountains-Pietown area

Quaternary Alluvium: (0-50 ft) GRAVEL, SAND AND MUD: Arroyo, valley and bolson deposits, alluvial-fan deposits and wind-blown sand. Piedmont-slope deposits masking much of Baca Formation not shown on Figure 1.

Late Tertiary Conglomerates: (0-100 ft) CONGLOMERATES and CONGLOMERATIC SANDSTONES: white, light gray, and grayish-pink, heterolithic conglomerates and crudely bedded conglomeratic sandstones, poor to moderately indurated, locally contains calcic paleosols. Northwesterly paleocurrent directions. Basal unconformity exposed at "Under the Mesa Well". Wedges out onto monadonock of older volcanic rocks at Taylor Hill; large blocks of basalt here probably derived from buried flows. Probably equivalent to "Fence Lake gravels" (Foster and others, 1959) and the Bidahochi Formation (Repenning and Irwin, 1954).

Mafic Dikes (late Oligocene): (10-20 ft wide): BASALTIC ANDESITE, black aphanitic dikes, weather to yellowish-brown, textures range from diabasic to vessicular, depending on erosion level. Dike system west of Pietown dated at 27.7 m.y. (Laughlin and others, 1980).

Rocks of the Datil-Mogollon Volcanic Field (Oligocene): (700-5000 ft). INTERMEDIATE PYROCLASTIC BRECCIAS, LAVAS, CONGLOMERATES and minor SANDSTONE: RHYOLITIC ASH-FLOW TUFFS: and BASALTIC-ANDESITE LAVAS: Thick pile (3000-5000 ft) preserved east of Red Lake fault zone is described by Harrison (1980) and by Osburn and Chapin (in prep). In map area west of Red Lake fault zone, the Dog Springs Member of the Spears Formation comprises the entire volcanic interval. Dog Springs Member: (700-1200 ft) QUARTZ LATITIC PYROCLASTIC BRECCIAS, with minor SANDSTONES: Light gray, pinkish-gray, pale red, cliff forming, crudely bedded mudflow breccias and tuff breccias; basal 50-70 ft consists of parallel-bedded sandstones. Sandstone partings between mudflows become thicker and more common to the west. Characterized by complex internal folding presumably related to soft-sedimentary deformation.

Baca Formation (Eocene): (1800-1900 ft) SANDSTONES, CONGLOMERATIC SANDSTONES, SILTSTONES, MUDSTONES and minor CONGLOMERATES: pinkish gray, light gray, pale red and yellowish-brown (rare), medium-to coarse-grained sandstones containing numerous pebbly lenses; intertonguing with reddish-brown mudstones, siltstones, and finer grained sandstones. Conglomeratic sandstones locally form thick outcrop belts (50-140 ft) believed to represent braided-channel complexes in a network of southeast- and northeast-flowing tributaries feeding an easterly flowing trunk stream. Basal conglomeratic sandstones contain abundant banded iron-oxide fragments derived from the underlying paleosol.

Table I, continued

Post-Crevasse Canyon Pre-Baca Paleosol (Paleocene?): (25-150 ft) OXIDIZED and BLEACHED CREVASSE CANYON SANDSTONES and SHALES, URANIUM DEPOSITS ALONG BASAL REDOX FRONT: light purplish-gray, light gray and maroon shales often mottled with yellowish-brown; interbedded with white, light gray, lavender and pale red to brick-red sandstones. Sandstones are fine- to medium-grained and commonly contain small concretions of hematite-limonite (after pyrite). Sandstones and shales often contain silicified logs. Banded iron oxide occurs sporadically as nodules in the altered rocks and as thin layers along sandstone-shale contacts. Basal redox front defined by greenish-gray sandstones (and radiometric anomalies) which generally follow sandstone-shale contacts but locally cut across sandstones as fossil roll fronts. These altered rocks are interpreted as the subsolum of a pre-Baca lateritic soil.

Crevasse Canyon Formation (Late Cretaceous): (1100-1700 ft)[1] SANDSTONES, SILTSTONES, SHALES and minor COAL: unaltered rocks below the paleosol are yellowish-gray and yellowish-brown fine- to medium-grained fluvial sandstones; interbedded with yellowish-brown shales, dark gray carbonaceous shales, thin silt-sandstone beds and thin coal seams. Sandstones commonly contain coalified wood and leaf debris, small ironstone concretions (pyrite-limonite), dark-brown carbonate concretions and clay galls. Low sinuosity channel complexes trend northeast to east-southeast.

[1] Total thickness of Crevasse Canyon Formation including altered rocks of pre-Baca paleosol

STRATIGRAPHY AND URANIUM MINERALIZATION PATTERNS

Uranium occurrences and deposits are found in three different stratigraphic horizons that crop out on the northern flank of the Datil Mountains (fig. 1). Two horizons--The Crevasse Canyon Formation and the Baca Formation--are rock-stratigraphic units and the third horizon is a thick paleosol developed on and within the upper Crevasse Canyon Formation. Most of these uranium occurrences had been located and described long before this study (Melancon, 1953; Griggs, 1954; Bachman and others, 1957; and Collins, 1957). The purpose of this section is to describe the character of the three host horizons, and to describe the common characteristics of the uranium occurrences, when grouped with respect to their hosts. When this is done, three different patterns of mineralization emerge that presumably are tied by genetic threads. These patterns appear to represent one primary mineralization episode and probably two (or more) episodes of redistribution of the primary mineralization.

The location and character of uranium occurrences were determined principally from radiometric anomalies defined with a hand-held gamma-ray scintillometer. Background gamma radiation of the Crevasse Canyon and Baca Formations normally ranged from 30 to 50 counts per second; however, unweathered (and unaltered) Crevasse Canyon shales often produced 60-90 counts per second. Intermediate volcanic breccias of the Spears Formation (Dog Springs Member) average 20 to 40 counts per second. Rhyolitic tuffs commonly exhibit high background radiation levels of about 60 to 100 counts per second. Radiometric anomalies observed in the map area ranged from 120 to 5000 counts per second.

Alteration of sandstone, overtly expressed by color patterns, is widely used in subsurface exploration for Wyoming-type roll-front deposits, (Anderson, 1969; Adler, 1970). However, color patterns in outcrops have been relatively under used in evaluating potential uranium districts (Vickers, 1957). As field work on this project progressed, an empirical association between color patterns and radiometric anomalies was developed to the point that color patterns could be used to spot additional mineralized outcrops in the "transition zone" and in the Baca Formation.

Crevasse Canyon Formation: Unaltered

The Crevasse Canyon Formation consists of interbedded sandstones, siltstones, shales (often carbonaceous) and a few coal seams. The correlation, age, and general depositional environments of the Crevasse Canyon Formation described here are substantially from Molenaar (1973, 1974 and 1977). The Crevasse Canyon is generally interpreted as fluvial sandstones and paludal shales deposited on a coastal plain adjacent to the northeastward prograding Gallup shoreline. In the Datil area, abundant wood and leaf debris in the Crevasse Canyon Formation suggest that this coastal plain was highly vegetated. The climate must have been wet and may have been tropical or subtropical. Flora from the Vermejo and Raton formations (Maastrichtian-Paleocene) in the Raton Basin of northern New Mexico indicate a wet, tropical climate during their deposition (Ash and Tidwell, 1976). Although younger than the Crevasse Canyon Formation, the Vermejo-Raton flora are probably indicative of the climate in the New Mexico region throughout Late Cretaceous time.

The age of the Crevasse Canyon Formation in the San Juan Basin is considered to be late Turonian to Coniacian or about 91-86 m.y. old (Molenaar, 1977). A sample of carbonaceous shale (RB-8) collected from the Red Basin area has yielded "Upper Cretaceous pollen and spores, not likely as old as Turonian nor as young as Campanian" (Karl R. Newman, 1981, written commun.). This shale was collected about 15 feet (stratigraphically) above the base of a bleached and mineralized sandstone assigned by Bachman and others (1957) to the base of the Baca Formation. As mapped in this study, the erosional unconformity at the base of the Baca Formation is about 30 feet (stratigraphically) above sample "RB-8". Thus, the pollen data are in general agreement with an assignment of this 45 foot interval to the Late Cretaceous Crevasse Canyon Formation. The questionable interval is assigned here to the Crevasse Canyon Formation and is interpreted as a pre-Baca paleosol (zone of weathering) that was developed on and within the Crevasse Canyon Formation.

Just northeast of the map area, the base of the Crevasse Canyon Formation rests conformably on the "C" tongue of the marine Gallup Sandstone (Molenaar, 1974). The Crevasse Canyon Formation (unaltered and altered) is unconformably overlain by the Baca Formation. Because of folding and poor exposures in the map area, which may hide normal faults that repeat the section, the best estimate of the thickness of the total Crevasse Canyon (unaltered and altered) is greater than 1100 feet and less than 1700 feet.

Only the upper quarter of the Crevasse Canyon was observed in detail during this project. The uppermost 200 to 300 feet of the Crevasse Canyon--generally upper half altered and lower half unaltered--locally forms mesas and cuestas around Alamocita Creek and Red Canyon. Bachman and others (1957) considered these upper mesa-forming beds to be marine deposits of the Point Lookout (?) Sandstone, but the author favors the interpretation "thick fluvial sandstones" as stated by Molenaar (1977, p. 164). These mesa-forming beds, which consist of about 60-70 percent sandstone and 30-40 percent interbedded shale, appear to represent northeast- and east-southeast-trending low sinuosity channel complexes (figs. 3 and 4).

Two types of sandstone beds are apparent in the upper Crevasse Canyon: 1) massive, channel-shaped sandstone beds, usually 10 to 20 feet thick (occasionally 40 feet thick); and 2) cross-bedded, ribbon-like (or sheet-like) sandstone beds about 5 to 15 feet thick, which typically form mesa caps and ledge caps. The massive sandstones are believed to represent coalescent and stacked channel deposits (braided or anastomosing) of low-water stages, and the ribbon-like sandstones may be flood-stage bed-load deposits characterized by transverse bar development. The Red Basin area appears to be in an interfluvial zone which contains relatively abundant carbonaceous shales. Massive channel sandstones are generally absent near Red Basin and cross-bedded sandstones are thinner and subequal to shales. Shale intervals commonly contain thin siltstone-sandstone beds that are thought to be splay deposits.

Occasionally, the Crevasse Canyon sandstones exhibit upward fining profiles and ripple laminations near their tops. The massive sandstones often exhibit internal scour surfaces and terminate abruptly against shales at cut banks. Coalified wood and leaf debris, small ironstone concretions (pyrite, limonite), large dark-brown carbonate concretions, and clay clasts are all common in the unaltered Crevasse Canyon sandstones.

Colors in the unaltered Crevasse Canyon Formation are considered to reflect early diagenesis and recent weathering. Weathered sandstones are mostly yellowish-gray, pale yellowish-brown, grayish-orange, sometimes light gray, and occasionally dark brown where well cemented with iron (?) carbonate. Planar cross-bedded sandstones appear to be preferentially cemented with dark brown carbonate.

In some canyon walls (particularly Remuda Canyon), erosion has cut through the modern weathered zone and exposed greenish-gray and olive-gray sandstones, which contain fresh pyrite concretions. In the subsurface, the Crevasse Canyon Formation (unaltered) is consistently colored in shades of gray, which is indicative of its regionally reduced character (Foster, 1964). Crevasse Canyon shales and siltstones are mostly medium gray or olive gray and occasionally yellowish brown in color. Carbonaceous shales are dark brown and black.

Radiometric anomalies in the unaltered Crevasse Canyon Formation are typically of low intensity (120-300 cps), laterally discontinuous, and have no visible signature, except in a common association with black carbonaceous material. The most significant occurrence of this type is apparently the "Midnight 2 mine"

(Bachman and others, 1957). Collins (1957, p. 7) reported production of 38 tons of ore grade material from carbonaceous sandstone lenses in the McPhaul Ranch area, most of which apparently came from the Midnight 2 mine. The host at the Midnight 2 mine is a southeast-trending channel sandstone containing pockets of carbonaceous debris. The northeastern cut-bank of the channel is well exposed in the pit walls.

Post-Crevasse Canyon Pre-Baca Paleosol

Bleached and oxidized Crevasse Canyon sandstones and shales that have been previously assigned to a "transition zone" between the Baca Formation and underlying Cretaceous rocks (Snyder, 1971; Johnson, 1978; Chapin and others, 1979) are here interpreted to be the subsolum ("C" horizon) of a post-Crevasse Canyon pre-Baca paleosol. This thick weathering zone of lateritic character has also been interpreted as 1) reworked Cretaceous rocks and assigned to the basal part of the Baca Formation (Bachman and others, 1957); and as 2) lower Baca beds intertonguing with Cretaceous rocks (Willard and Givens, 1958). Recently Pierson and others (1981, p. 17-18) have suggested that uranium deposits in the Crevasse Canyon Formation in the Red Basin area "probably formed by precipitation of uranium from groundwaters, which descended through sandstones of the overlying Baca Formation". In this case, the "transition zone" would be interpreted as a post-burial zone of groundwater alteration.

The recognition of the pre-Baca paleosol is based on criteria described by Birkeland (1974, p. 24-26). As pointed out by Birkeland, one person's buried soil horizon is often another person's geologic deposit--or another person's post-burial zone of ground-water alteration. The "transition zone" is clearly not a geologic deposit. Figures 1, 2 and 3 (p. 7, 17, 24) demonstrate that the "transition zone" is a laterally continuous zone of alteration, which was developed within -- and locally cuts across -- beds of the upper Crevasse Canyon Formation. Observations that indicate this zone of alteration predates the Baca Formation are: 1) the altered zone is distinctly scoured (thinned) by a paleovalley at Remuda Canyon, which was cut and back filled by a channel complex in the basal Baca Formation; and 2) the basal Baca beds locally contain abundant clasts of variably altered (colored) sandstones, shales and fragments of banded iron oxides. The presence of these clasts in the lower Baca, which are strikingly similar to rocks in the altered zone, are difficult to explain if not derived from a pre-existing zone of alteration. If the "transition zone" and its related uranium deposits are attributed to the downward percolation of uranium-bearing groundwaters through the Baca Formation, then the zone of altered Cretaceous rocks should be thickest where the lower Baca has the best aquifer characteristics. Thus, the thickness of a post-Baca alteration zone should be greatest along the paleovalley at Remuda Canyon, which is exactly opposite of the observed relationship (fig. 2).

The post-Crevasse Canyon pre-Baca paleosol has the general characteristics of pedalfer soils, which typically form in well-drained areas in wet climates. Organic materials and carbonate have been leached from the upper portions of the paleosol, local zones of banded hematite nodules are visible signs of iron

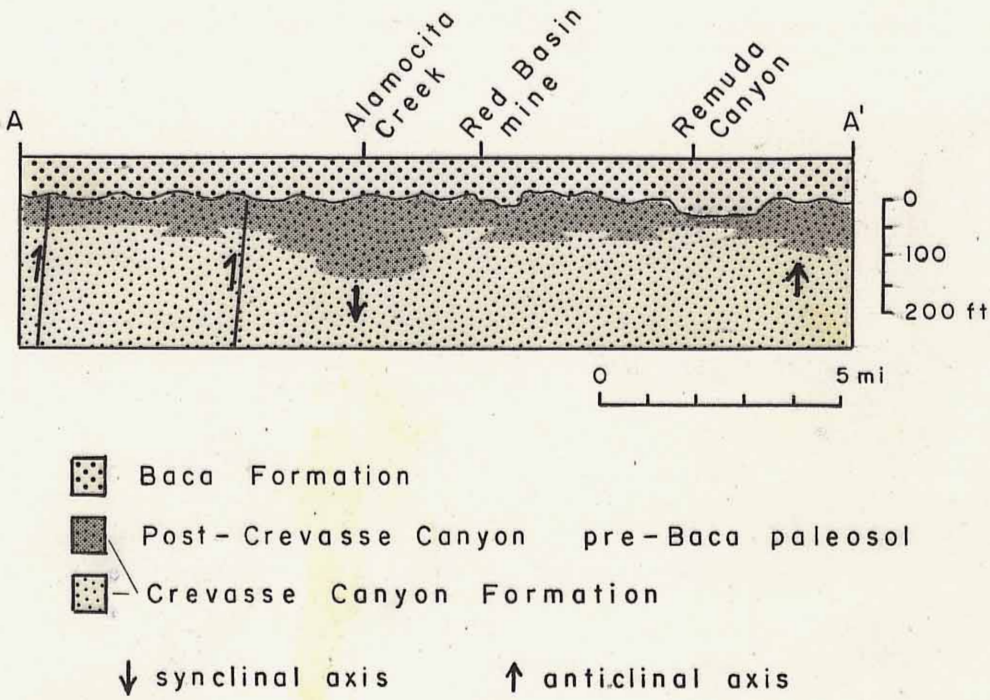

Figure 2 - Diagrammatic cross section illustrating the stratigraphic relationships of the post-Crevasse Canyon pre-Baca paleosol. Cross section is reconstructed to early Baca time (Eocene). Attitude and sense of movement on pre-Baca faults are uncertain.

enrichment, and the presence of numerous silicified logs demonstrates the redistribution of silica. The pre-Baca paleosol is similar to lateritic soils (oxisols) found today in tropical uplands (Mohr and Van Baren, 1954; Thomas, 1974), and it is also similar to red-yellow podzolic soils (ultisols) found today on the coastal plains of the southeastern United States (Hunt, 1972). Lateritic soils and weathering profiles, which are as much as 100-300 feet thick, represent the highest degree of chemical weathering in the hottest and wettest climate. Podzolic soils and weathering profiles, which are generally 10-30 feet thick, represent a lesser degree of intense chemical weathering in a warm and wet climate. Thus, the relatively great thickness of the pre-Baca subsolum (150 feet) is the best indication that it formed below a lateritic soil in a tropical climate. By definition, lateritic soils contain laterite, which is a hardened layer of iron oxide commonly exhibiting pisolitic and banded structures. Abundant fragments of banded iron oxide in the base of the Baca Formation were probably derived from such a laterite horizon on the pre-Baca paleosol. In thin section, these fragments of banded hematite-limonite, hematized sandstone, and hematized siltstone are very similar in appearance to photomicrographs of hardened laterite from Africa (Alexander and Cady, 1962).

As stated in the previous section, the organic-rich Crevasse Canyon beds were most likely deposited on a tropical or subtropical coastal plain. Thus development of the post-Crevasse Canyon lateritic soil would only have required a regional lowering of the water table. This inferred lowering of the water table may have been tectonically initiated and reflect the northeastward retreat of the Late Cretaceous seaway out of the New Mexico area.

It should not be surprising that uranium deposits could form in the lower portion of a lateritic or podzolic soil. Groundwaters in these open chemical systems are rich in organic acids, which may carry metallic ions, such as uranium, in chelated or other complex forms. Precipitation of these metals could then occur at redox boundaries in the saturated zone. Red podzolic soils found today on the coastal plains of North Carolina are marked at their base by either a less permeable layer or a greenish-gray sand (Daniels, Gamble and Holzhey, 1975). These greenish-gray sands are commonly referred to as "soil gleys" and apparently represent amorphous concentrations of ferrous iron and clay. In North Carolina, these soil gleys not only mark the iron redox boundary, they also occur at the base of the zone of active groundwater flow and are associated with an abrupt increase in pH (Holzhey, Daniels and Gamble, 1975).

The pre-Baca paleosol is an indication of non-deposition and non-erosion that appears to require a period of "inter Laramide" tectonic stability. The fossil soil most likely represents an interval of time significantly less than its potential 41 million years (86 m.y. ago to 45 m.y. ago). A loosely constrained period of time between "early Laramide" wrench-fault structures and "late Laramide" vertical uplifts in central New Mexico (Slack and Campbell, 1976) suggests that the pre-Baca fossil soil may have formed between late Paleocene and middle Eocene time. Chapin and Cather (1981) have concurrently recognized this period of inter Laramide quiescence, which they interpret as occurring in the late Paleocene on the basis of a similar paleosol in the Denver Basin (Soister and Tschudy, 1978). The pre-Baca paleosol is therefore tenatively interpreted to be late Paleocene in age. Lateritic weathering profiles similar in character and age to the pre-Baca paleosol, are widely recognized in the Rocky Mountain and Great Plains states of Colorado, Wyoming, South Dakota and Nebraska (Pettyjohn, 1966; DeGraw, 1969; Soister and Tschudy, 1978), and along the southern states from Arkansas to Georgia (Hunt, 1972, p. 154). Equivalents of the pre-Baca paleosol have been observed in the Quemado area and the Gallinas Mountains area, but its extent throughout New Mexico is presently unknown (see fig. 5).

The upper contact of the post-Crevasse Canyon pre-Baca paleosol (also the upper contact of the Crevasse Canyon Formation) is an erosional unconformity, of generally low relief, that is buried by conglomeratic sandstones of the Baca Formation. Locally the paleosol is scoured by southeast-trending paleovalleys. The largest of these paleovalleys, about one mile wide and 50 feet deep, nearly truncates the paleosol in the Remuda Canyon area (see figs. 1 and 2). This bedrock channel is filled with quartzite cobble conglomerates and sandstones of the Baca Formation deposited by a high energy, braided stream. Small paleovalleys (10-20 feet deep) are also evident near the Red Basin mine.

The lower contact of the post-Crevasse Canyon pre-Baca paleosol was originally a subhorizontal, but locally irregular, oxidation-reduction interface in a shallow groundwater system of regional extent. This widely mineralized interface has been upwarped and cut by erosion in late Teritary time to produce the southward dipping irregular contact that bounds the north side of the paleosol as shown on Figure 1. Much, but not all, of the uranium has been leached from the base of the paleosol in the surface outcrops. In outcrop, the basal alteration front of the paleosol is obviously controlled by permeability (transmissivity) contrasts and generally follows sand-shale contacts. However, the alteration front also locally cuts across channel-shaped sand bodies, especially near their margins. At the Red Basin mine and elsewhere, altered sands at the base of the paleosol intertongue with carbonaceous shales of the unaltered Crevasse Canyon Formation. Where this situation occurs the base of the paleosol is mapped at the base of the lowest altered sandstone.

The most revealing outcrop that led to the recognition of the pre-Baca paleosol, is a "ghost roll front"[1] (terminology of Anderson, 1969) exposed north of Alamocita Creek (NW¼, NE¼, Sec. 11, T. 2 N., R. 11 W.; in draw at elev. of 7700 feet). This one outcrop clearly demonstrates that the red, lavender, and white sandstones characteristic of the paleosol ("transition zone") are altered equivalents of yellowish sandstones typical of the Crevasse Canyon Formation. It was the observation of this fossil roll front that permitted mapping of the alteration-mineralization patterns shown on Figure 3.

The present thickness of the pre-Baca paleosol is a combination

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[1] The writer prefers "fossil roll front" or "alteration front" for this bold and colorful outcrop, which has apparently been leached of its uranium content, because it is much more visible than a "ghost".

of its original thickness minus scouring of its upper surface in early Baca time. Estimates of the present thickness of the paleosol range from 25 feet at Remuda Canyon to about 150 feet at Alamocita Creek. In most areas, the thickness of the paleosol is between 60 and 100 feet (fig. 2). Thicknesses less than 60 feet appear to indicate significant scouring of the upper surface of the fossil soil.

The original thickness of the paleosol was controlled by the depth of active (and oxidizing) groundwater flow (see Lelong and others, 1976), which presumably would not have been much below the valley floors. Lateral variations in the thickness of the paleosol should thus reflect the paleolandscape and its complex interaction with vertical and lateral permeability trends in the Crevasse Canyon beds. Gentle folding of the Crevasse Canyon beds prior to soil development also appears to have controlled groundwater flow directions and the resulting alteration-mineralization patterns in the paleosol.

The paleosol is generally divisable into an upper barren zone and a lower mineralized zone. The upper barren zone is characterized by alteration of both sandstones and shales with no apparent respect for permeability contrasts. The upper zone probably represents the dominantly unsaturated portion of the soil where vadose water generally percolated downward to the water table. The lower mineralized zone is a zone of groundwater alteration and mineralization visibly controlled by permeability contrasts between sandstones and shales. In the lower zone, altered sandstones may appear to intertongue with unaltered shales, or grade into unaltered sandstone and shales. Alteration of sandstones in the lower zone may locally be spotty or incomplete. The lower mineralized zone is believed to represent the zone of laterally flowing, oxidizing groundwater in the uppermost tens of feet of the saturated zone. The mineralized zone was best developed in near-surface aquifers like the fluvial channel complex at Alamocita Creek. The barren zone would have formed most of the weathered interval in upland areas and would have been thinnest in lowland areas. However, the mineralized zone was probably relatively constant in thickness (20-50 feet). Alteration-mineralization patterns, in the Alamocita Creek area, appear to reflect complex groundwater flow patterns with an overall hydrologic gradient toward the east (fig. 3).

The general lithology of the pre-Baca paleosol is that of the Crevasse Canyon Formation on which it was developed. Thus the paleosol consists of fine- to medium-grained sandstones interbedded with shales and siltstones. The ancient weathering profile is distinguished from the Crevasse Canyon Formation primarily by its different colors, which presumably reflect changes in mineralogy and chemistry.

Pastel colors dominate in the subsolum of the pre-Baca soil. "Massive sandstones" (see Crevasse Canyon Formation) are dominantly light purplish gray (lavender) and pale red in color and occasionally may be light gray or brick red. Cross-bedded sandstones are usually bleached white or light gray. However, the cross-bedded sandstones also appear to form unaltered yellowish-gray cap rocks on lavender and red massive sandstones in the Alamocita Creek area. Shales in the paleosol are mostly light purplish-gray or

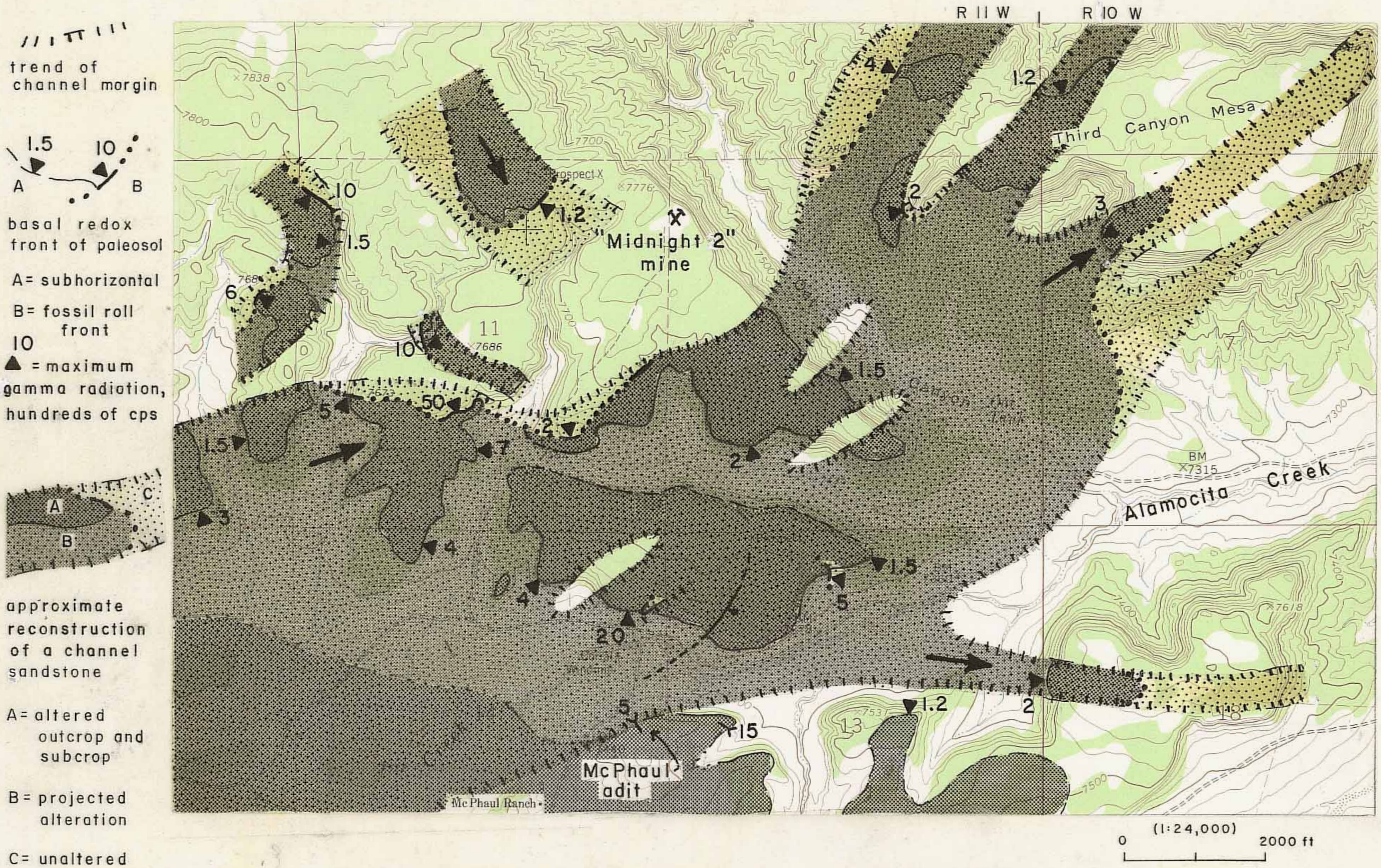

Figure 3 - Map of alteration-mineralization patterns in the lower zone of the pre-Baca paleosol, where developed on a fluvial channel complex in the upper Crevasse Canyon Formation. Base map is from Third Canyon 7.5 minute quadrangle.

light gray, and often mottled with yellowish-brown. Maroon-colored shales are rare. The altered shales are generally restricted to the upper portion of the paleosol, but may also occur along the base of reddened sandstones where they have been observed to grade downward into unaltered carbonaceous shales. The altered sandstones and shales commonly contain silicified logs and hematite-limonite concretions. Nodules of banded iron oxide are common in altered sandstones and shales near Alamocita Creek and northwest of Alamocita Creek. Banded iron-oxide also occurs as thin layers along sand-shale contacts. Carbonate concretions and carbonaceous material, which are common throughout the unaltered Crevasse Canyon are notably absent in the upper zone of the paleosol and uncommon in the lower zone.

Low grade radiometric anomalies (120-200 cps) are essentially continuous along the basal alteration front of the paleosol. The basal alteration front generally follows sandstone-shale contacts; however, it also locally cuts across sandstone beds as fossil roll fronts. These alteration fronts are commonly "sharp" and marked by greenish-gray bands. Preliminary petrographic study indicates the greenish colors reflect an abundance of chlorite and iron-rich clays (montmorillonite?). Radiometric anomalies of 500 to 2000 counts per second have been observed at most of the sinuous and "C" shaped alteration fronts exposed in the Alamocita Creek area (fig. 3). The longest exposure of one of these fossil roll fronts (SE¼, NE¼, SW¼, Sec. 11, T. 2 N., R. 11 W.; elevation 7570 feet) locally has a radiometric anomaly of 5000 cps in a calcite cemented zone immediately adjacent to the greenish-gray band. A chemical analysis of a sample from this calcite-cemented zone yielded only 0.02 percent U_3O_8, which indicates significant secular disequilibrium caused by recent leaching of uranium. A few sharp alteration fronts have apparently been completely leached of both uranium and daughter nuclides; appropriately they have no radiometric anomaly associated with them. Similar sharply defined fossil roll fronts are exposed in Ox Spring Canyon, Pine Canyon, and near Red Canyon.

Gradational, and apparently unmineralized, alteration boundaries have locally been observed. In the Cal Ship Mesa area, reddened sandstones grade laterally into yellowish-gray sandstones over a distance of 25 to 50 feet. These gradational alteration boundaries are not associated with greenish bands or with radiometric anomalies; however, at their base the same reddened sands have greenish bands and radiometric anomalies like those near Alamocita Creek. The geometry (and transmissivity?) of mesa-capping sandstones was probably less favorable for the development of roll fronts. At the Red Basin mine and McPhaul adit (Bachman and others, 1957), the radiometric anomalies are associated with thin greenish-gray bands that follow the base of the bleached sandstones where they rest on carbonaceous shales. Only one location was found where a mesa-capping sandstone appears to be cut by a fossil alteration front (center SE¼, Sec. 11, T. 2 N., R. 11 W., along road at elevation of 7630 feet).

Secular disequilibrium relationships, which are apparent from the data of Bachman and others (1957, Table 1), indicate that all surface exposures of uranium deposits in the base of the pre-Baca paleosol have been partially leached of their uranium content within the last 750,000 years. However, the Red Basin deposit, which occurs above a carbonaceous shale in the shallow subsurface, has been enriched in uranium in late Quaternary time.

In the Remuda Canyon-Red Canyon area the basal alteration front of the pre-Baca paleosol is relatively less radioactive. In the floor of Red Canyon, wispy patches of greenish-gray sandstone occur in a bleached ledge-forming sandstone, which suggests that this altered sandstone was once mineralized. In this area uranium may have been partially flushed out of the paleosol by shallow groundwaters migrating along the large Baca-filled paleovalley in early Baca time.

Baca Formation

The Baca Formation, as mapped on Figure 1, consists of mudstones, siltstones, sandstones, conglomeratic sandstones, and a few conglomerates. The overall red color of the Baca is imparted by the abundant reddish mudstone beds. The Baca Formation is generally interpreted as fill of a Laramide basin. The primary source of the Baca Formation was the Mogollon Highland, in what is now southwestern Arizona. The Zuni and Morenci uplifts, respectively to the north and south, also provided Baca sediments to the Datil Mountains-Pietown area. Thesis studies by Snyder (1971), Johnson (1978) and Cather (1980) have provided a framework for the depositional history of the Baca Formation, and are drawn on freely in this discussion.

The age of the Baca Formation, as indicated from a few vertebrate fossils, is middle Eocene to early Oligocene (?), or about 45-38 m.y. old (Gardner, 1910; Snyder, 1971, Cather, 1980; and Schiebout, 1981). Field relations in the Datil Mountains area suggest that the oldest Baca beds lie south of the outcrop area, along the original axis of the Baca basin. The older beds probably wedge out to the north and are overlapped by successively younger beds. Similar onlap relationships are visible along the paleovalley wall in the Red Canyon area.

The Baca Formation rests in erosional unconformity and locally in angular unconformity on the Crevasse Canyon Formation. The Dog Spring Member of the Spears Formation (Osburn and Chapin, in prep.) conformably overlies the Baca Formation. However, the upper contact of the Baca Formation is generally masked by colluvium. Rare exposures of the Baca-Spears contact indicate that it is approximately located at the base of 300-ft-high cliffs formed by the Dog Springs Member in the Datil and Sawtooth Mountains. Most of the Baca Formation in the map area is masked by piedmont gravels that are not shown on Figure 1. A sample of the Dog Springs Member from the northeast Datil Mountains has yielded a K-Ar age of 38.5 m.y. (C.E. Chapin, 1981, oral commun.); this requires most of the Baca Formation in the Datil Mountains to be of Eocene age. Near Red Canyon, the Baca Formation is estimated to be 1800 to 1900 feet thick. Snyder (1971) reported a measured section of 1162 feet for the Baca Formation in this area. Apparently Snyder's section does not include as much as 600 feet of upper Baca, which is locally covered by colluvial deposits derived from the Spears Formation.

Three roughly defined lithologic facies of the Baca Formation are recognized from this reconnaissance work. They are: 1) a basal facies (zone) that contains abundant clasts of Crevasse Canyon affinity (both altered and unaltered); 2) a fluvial-channel facies consisting of thick packages (50-140 feet) of coarse-grained conglomeratic sandstones that form light colored (light-gray, pale red, sometimes pale yellowish-brown) generally lenticular outcrops; and 3) an interfluvial facies consisting of interbedded mudstones and sandstones that are mostly reddish colored. These lithologic facies have gradational intertonguing boundaries, which are essentially unmappable because the Baca Formation is poorly exposed in most areas. The basal regolithic zone is a compositional subfacies within both the fluvial channel facies and the interfluvial facies.

The basal facies is usually a light brownish-gray or light gray sandstone that is almost always conglomeratic. Nearly ubiquitous fragments of banded hematite-limonite, which range from pebble to sand-sized grains, distinguish these reworked Cretaceous sands from similarly colored bleached Cretaceous sands that were altered (in-situ) in the paleosol. As previously stated, these banded iron-oxide fragments are believed to represent hardened laterite eroded from the upper layers of the pre-Baca lateritic soil (see post-Crevasse Canyon pre-Baca paleosol). Other clasts (the Crevasse Canyon and pre-Baca-paleosol affinity) found in the basal Baca consist of reddish, yellowish, and white (rare), fine- to medium-grained sandstones; light gray and yellowish-brown shales, and silicified wood. Quartzite and other well-indurated pebbles derived from outside the map area increase in size and abundance toward the large paleovalley at Remuda Canyon (fig. 1). In this southeast-trending (flowing) paleovalley, the basal Baca consists dominantly of quartzite cobble conglomerates. Some conglomerates appear to be cross-bedded sieve deposits, which are distinctive of braided streams (cf. Johnson, 1980, p. 57).

The fluvial-channel facies consists predominantly of medium- to coarse-grained sandstones, which are mostly friable and quite permeable. Because of poor induration, conglomerate lenses typically weather to areas covered with abundant well-rounded pebbles (lag gravels). Festoon cross bedding, scour surfaces and horizontal lamination are common. Upward fining units, planar-cross bedding, and mudstone breaks are rare. In the Datil Mountains-Pietown area, channel-facies sandstones appear to represent deposits of braided (and meandering?) streams in a network of southeast and northeast flowing major tributaries that fed an easterly flowing trunk stream. Johnson (1978) observed all but the northeast flowing tributary, which is poorly exposed near Pietown (see fig. 4). The observed paleocurrent directions of both the channel facies and interfluvial facies allow a rough subdivision of the Baca into lower, middle and upper sediment packages with southeast-, east-, and northeast-, trending depositional fabrics, respectively. These "fabric" packages are stacked, stratigraphically, on the north flank of the Datil Mountains. This relationship seems to require that the east-trending trunk stream moved from south of the outcrop belt to north of the outcrop belt during deposition of the Baca. This inferred shift in basin configuration may reflect progressive development of the Laramide Morenci uplift as defined by Cather (1980). The Morenci uplift lies about 20 miles south of the Datil Mountains, in an area that is now largely under the San Augustin Plains. Stearns (1962) recognized a remnant of this early Tertiary uplift exposed in the Horse Mountain area. The projected northeastward continuation of the Morenci uplift has been described by Chapin and others (1979, p. 22).

The interfluvial facies consists of alternating beds of mudstone and sandstone, which are usually 5 to 20 feet thick and tend to form stepped profiles where well exposed. The reddish-brown and reddish-orange mudstone beds often exhibit zones of greenish-gray root mottling and white carbonate nodules near their tops. These upper zones of the mudstones are interpreted as slightly to moderately developed pedocal soil horizons typical of a semi-arid desert climate. One such mudstone outcrop (NW/4, NW/4, Sec. 9, T. 1 N., R. 11 W.) also exhibits polygonal mud cracks, which are filled with sandstone dikelets that extend several feet downward from the overlying sandstone bed. Similar caliche type paleosols have been observed in the Baca Formation of the Gallinas Mountains (Cather, 1980). In general, the mudstone beds of the interfluvial facies may be interpreted as suspended load deposits emplaced on wide flood plains or playas between the major braided streams of the channel facies. Pale red sandstone beds of the interfluvial facies are mostly fine- to medium-grained and commonly have upward-fining profiles. These interfluvial sandstones may represent deposits of small meandering creeks and some sheet-splay deposits. Beds of coarse-grained congomeratic sandstone, which are typical of the fluvial facies, are locally interbedded with the overbank mudstones.

Uranium occurrences in the Baca Formation are typically associated with dusky purplish-red or dusky red lenticular bands of fine- to medium-grained sandstones, which are found mostly within the coarse-grained channel sandstones. Similar occurrences have also been observed in sandstones of the interfluvial facies. These radiometric anomalies generally range from 120 to 300 counts per second, with a maximum of 600 counts per second. The anomalies, at first, appear to be of syngentic origin, since the distinctive color bands are commonly truncated by scour surfaces or feather out into coarser-grained sandstones. However, the dark color bands are also associated with irregular bleached (light gray) areas in the pale red sandstones, which suggests that they are epigenetic occurrences pseudomorphing syngenetic features in the Baca Formation. These dark-colored, uraniferous bands are believed to represent placer-like accumulations of iron oxides (magnetite, ilmenite, hematite?) that have extracted uranium from groundwaters by weak redox reactions or adsorption (see Langmuir, 1978). The majority of these pseudo-placer uranium anomalies occur in sandstones of the channel complex which filled the paleovalley between Remuda Canyon and Red Canyon. Similar occurrences were found (but appear to be less abundant) in the east-trending, trunk-stream sandstones of the Baca Formation (fig. 4). These relationships suggest that uranium was "flushed" into developing Baca aquifers by erosion of the uranium-rich lateritic weathering profile from the late Laramide uplifts and their basin margins. No uranium occurrences were found in sandstones of the upper Baca, but this may be attributed to the poorly exposed nature of the upper Baca and a lower frequency of observations.

The Hook Ranch prospect, in the Gallinas Mountains, contains uranium minerals associated with carbonized wood in a coarse-grained fluvial sandstone of the upper Baca Formation (Bachman and others, 1957; Chapin and others, 1979; Cather, 1980). No uranium occurrence of this type was observed in the Baca Formation of the Datil Mountains-Pietown area.

The thick (120-140 feet) axial stream sandstones may form a wide belt-shaped body in the subsurface (rising stratigraphically to north). This generally gray, bleached looking, sand body contains some uranium anomalies and has excellent aquifer characteristics. However, no carbonaceous debris has been observed in these sandstones, and the Baca outcrops are generally of oxidized character in the Datil Mountains area. The capacity of the Baca channel sandstones to act as a subsurface trap for uranium deposits is presently unknown.

GENETIC EXPLORATION MODEL

Table 2 is offered here as an untested conceptual model that may explain the origins of the various types of uranium deposits and occurrences in the Datil Mountains-Pietown area. The genetic model is based on the geologic history of the area as it may pertain to initial concentration, preservation and redistribution of uranium deposits in the area. The heart of the model is the post-Crevasse Canyon, pre-Baca paleosol. Other elements of the model are largely speculative, but are in agreement with the available data. This genetic model will certainly need modification as new facts become available, but its heart is expected to remain unbroken. The model is organized as a geologic history of three stages of uranium mineralization and presented in an outline format to avoid too much speculation. The timing of some events is not well constrained; thus some events listed in separate chronological groups may have occurred contemporaneously (or vice versa). Footnotes are used to support events not previously discussed in this report. Because modern and ancient soils are widespread indicators of climatic conditions, this genetic exploration model should have implications outside the study area (see Epilogue). However, the model is presented primarily as a framework for future uranium exploration in the Datil Mountains-Pietown area.

TABLE 2. Genetic exploration model for uranium deposits in the Datil Mountains-Pietown area.

I. Pre-mineralization stage (late Cretaceous)

A. deposition of fluvial sands and paludal carbonaceous shales of the Crevasse Canyon Formation

B. syngenetic or diagenetic concentration of 10-25 ppm uranium in Crevasse Canyon shales[1]

C. early Laramide en echelon folding and faulting of carbon-rich Crevasse Canyon beds

II. Primary mineralization stage (Paleocene?)

A. development of a lateritic soil and weathering profile (as much as 150 feet thick) on upper Crevasse Canyon beds; hot-wet climate; dropping water table; during inter-Laramide period of stability

1. acidic[2] leaching of uranium and other elements in upper vadose zone, uranium mostly from shales

2. soilwaters rich in organic acids transport uranium and other elements in actively flowing portion of saturated zone (approx. 20-50 feet thick), complex flow patterns (generally to east) in folded fluvial sandstone aquifers; alteration of aquifer sandstones, deposition of uranium and other elements in soil gley zones formed at redox boundaries between actively flowing groundwater and relatively stagnant waters, forms primary roll-front and tabular deposits.

III. Post-mineralization stage; preservation and partial redistribution (Eocene to present)

A. development of late Laramide uplifts, hot-dry climate

1. erosion of lateritic soil from uplifts and basin margins, flushing of uranium-rich waters into Baca basin

2. local scouring and flushing of lateritic soil in Datil Mountains area by southeast flowing waters

3. spotty entrapment of uranium by placer-like iron oxide concentrations in Baca channel sands

B. burial and preservation of lateritic soil and related uranium deposits by 3000-5000 feet of Baca and volcanic strata in Eocene, Oligocene and early Miocene time

TABLE 2. Genetic exploration model - continued

III. Post-mineralization stage (cont'd)

C. Late Cenozoic faulting, south tilting of strata, followed by epeirogenic uplift (late Miocene-Pliocene)

1. truncation of south-tilted paleosol by north-facing pediment; flushing of uranium by northerly flowing waters, entrapment of uranium in carbonaceous sandstones of lower Crevasse Canyon

2. local uplift and subsidence related to faulting; erosion sedimentation and redistribution of uranium continues to present time; uranium-rich ground waters near Pietown are spatially related to Hickman fault zone[3]

3. primary roll-front and tabular uranium deposits in base of pre-Baca paleosol are probably preserved below the present water table[4]; secular disequilibrium indicates fossil roll-front deposits are strongly leached of uranium above the modern water table, near surface tabular deposits associated with carbonaceous shales (as at Red Basin) have been recently enriched with uranium[5]

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[1] a drill hole (T.D. 528 feet) in Crevasse Canyon equivalent, near Fence Lake, NM, has intersected numerous shales that average 10 ppm eU and contain as much as 25 ppm eU (Frank Campbell, 1981, oral commun.).

[2] see Hunt (1972, p. 191; cf. Gabelman, 1970).

[3] compare Maassen (1980, pl. 3) with Figure 1; other uranium anomalies in well waters near Quemado appear to be associated with unmapped fault zones.

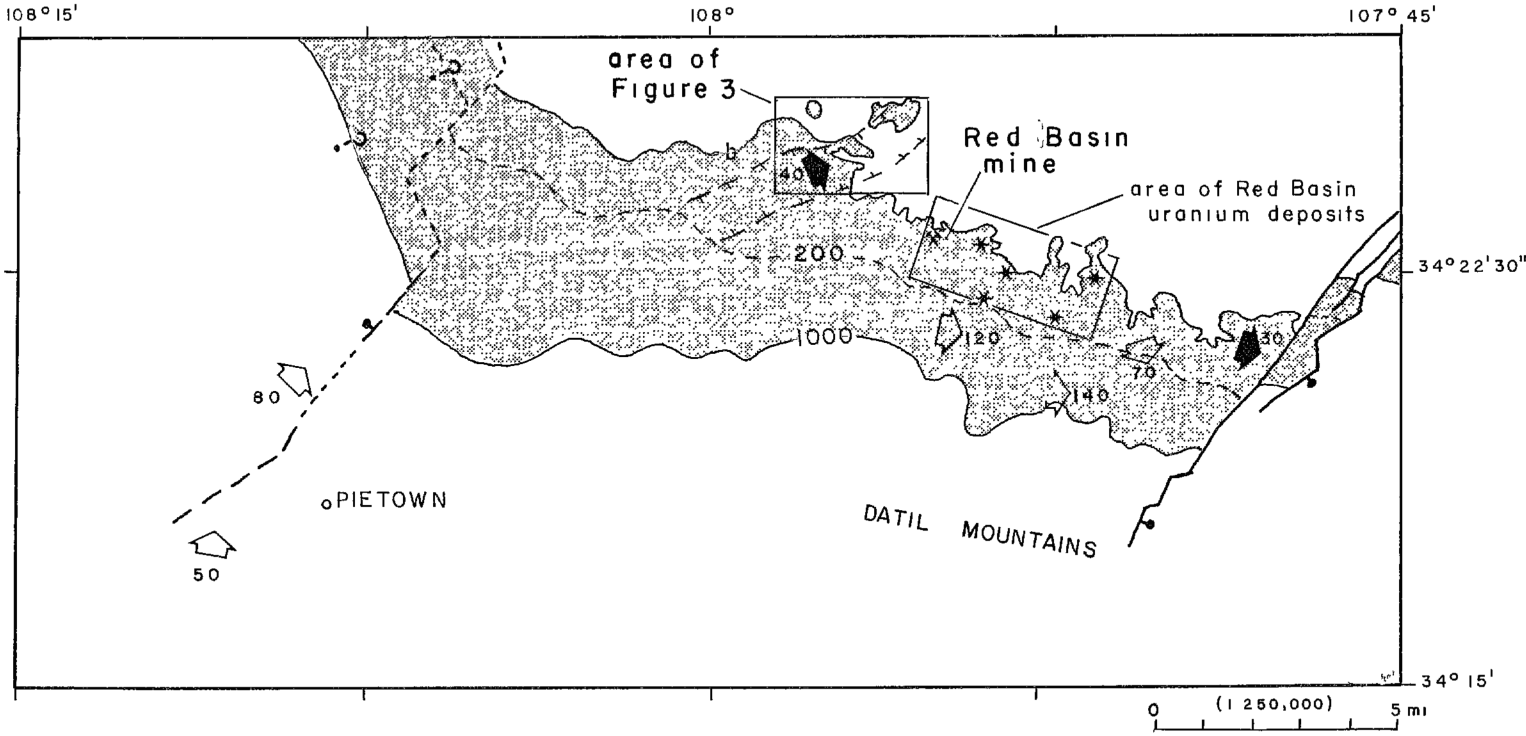
[4] in Wyoming similar roll-fronts are generally preserved below the water table (Anderson, 1969; Harshman, 1970); strongly reduced formations (like the Crevasse Canyon) resist deep oxidation by groundwaters (Saucier, 1980).

[5] see Bachman and others (1957, Table 1, sample numbers 15-18)

URANIUM POTENTIAL

Chances for discovery of additional uranium deposits in the Datil Mountains-Pietown area are excellent. The most favorable and largely untested areas for shallow exploration drilling (target depth less than 1000 feet) are delineated on Figure 4. The primary exploration target is the southerly dipping subsurface projection of the post-Crevasse Canyon, pre-Baca paleosol, which hosts uranium deposits in the Red Basin area.

Numerous fossil roll fronts, which are mostly leached of their original uranium content, are exposed along the upturned and eroded edge of the pre-Baca paleosol. Unleached roll fronts of similar geometry and orientation are probably preserved in the down-dip projection of the paleosol where it lies below the water table, which is generally at a depth of 200 to 500 feet (Wilson, 1981, p. 51). Based on the fossil roll fronts in the Alamocita Creek area (fig. 3), the preserved ore rolls could be as much as a mile long, 40 feet high and 30 (?) feet wide. The mineralized zone is confined to the basal 20 to 50 feet of the ancient weathering profile. The small ore rolls are likely to be broken by numerous shale splits. The flow patterns of mineralizing groundwaters were complexly controlled by aquifer trends, broad folds in the bedding, and paleotopography during soil development. Thus, the orientation and geometry of preserved ore rolls should be unrelated to the present southerly dip in the Datil Mountains area, which was superimposed on the buried weathering profile in late Cenozoic time. Ore rolls should be developed along margins of large paleochannel complexes in the



favorable area where uranium-bearing paleosol is at depth of less than 1000 feet

approximate depth contour on base of paleosol
- —b— exposed base
- --200- 200 feet (near water table)
- —1000— 1000 feet

location and trend of fluvial channel complex

40 Crevasse Canyon Fm. 70 Baca Fm. (number indicates maximum sandstone thickness in feet)

approximate margins of channel complex

Figure 4 - Favorable areas for shallow uranium exploration in the Datil Mountains--Pietown area. Roll front deposits probably preserved below water table (200-500 feet).

upper Crevasse Canyon Formation, such as the one exposed near Alamocita Creek (fig. 3). The down-dip (originally upstream) projection this paleochannel complex is the most favorable exploration target in the map area. The subsurface distribution of such fluvial sand belts in the upper Crevasse Canyon is not known, nor is the effect of pre- and post-mineralization folding and faulting on their distribution.

A semiquantitative estimate of the uranium potential of the Datil Mountains-Pietown area may be extrapolated from published data on the Red Basin ore reserve area (DOE, 1980; Colorado Plateau assessment report no. 37). This DOE assessment report implies reserves (95 percent probability) of about 1.6 million pounds of U_3O_8 at an assigned average grade of 0.31 percent U_3O_8, which is based on a given forward cost of 30 dollars per pound. The same report classifies the Red Basin deposits as "channel-controlled stratiform" and assigns the Baca Formation as their host. Six locations of shallow subsurface uranium deposits have been inferred in the Red Basin area on the basis of closely spaced drill holes and active claim blocks (figs. 1 and 4). Four of these apparent uranium deposits, one of which is at the original Red Basin mine, are clearly in the paleosol horizon below the Baca Formation. The other two inferred deposits may be reasonably interpreted as occurring in the shallow subsurface projection of the paleosol. Thus, the DOE assignment of the Red Basin uranium deposits to the Baca Formation is considered to be incorrect. These stratiform (tabular) deposits in the shallow subsurface of the Red Basin area probably represent tails of roll fronts that were preserved above the water table because they occur along contacts of sandstones with carbonaceous shales. The Red Basin area appears to be in an interfluvial zone (facies) where carbonaceous shales are relatively abundant.

The area around the Red Basin deposits represents about 8 square miles within the favorable 82 square miles shown on Figure 4. Since the inferred 1.6 million pounds U_3O_8 in the Red Basin area does not include roll deposits, the potential of adjacent areas, which probably contain primary ore rolls below the water table, should be at least as great as the Red Basin area, and could be several times greater. Therefore the relatively unexplored 74 square miles remaining in the favorable area should contain at least 14.8 million pounds U_3O_8, and could contain 30-45 million pounds U_3O_8.

It cannot be demonstrated here, that the Baca Formation in the Datil Mountains-Pietown area has a significant uranium potential. The subsurface projections of the large braided-channel complexes shown on Figure 4 represent targets of uncertain potential. The lower and middle Baca sandstones have apparently carried some uranium. However, it is unlikely that these aquifer sandstones contain enough reductants to have trapped uranium in deposits large enough to be commercially exploitable. If subsurface data indicate that the Baca Formation does contain a widely reduced facies, than its uranium potential could be of economic significance. Sparse drill-hole data available for the Baca Formation in the Quemado area indicate that it is red and of oxidized character in the subsurface (Foster, 1964, p. 7 and 13).

EPILOGUE

Because soils are widespread indicators of climatic conditions, uranium deposits similar to those in the Red Basin area may have formed and may be preserved in many other areas of New Mexico, and the southern Rocky Mountains. Remnants of early Tertiary basins in New Mexico where the uranium-bearing Paleocene (?) paleosol may be preserved are shown on Figure 5. In the San Juan and Raton basins, equivalents of the pre-Baca paleosol could be poorly developed or not apparent because of contemporaneous sedimentation during the favorable climatic period. Where preserved in early Tertiary basins of southern New Mexico, these fossil soils should be locally truncated by Eocene erosion surfaces along the basin margins.

Many questions concerning the post-Crevasse Canyon, pre-Baca paleosol have not been raised and many others have not been satisfactorily answered. Questions on the chemistry and mineralogy of the pre-Baca paleosol, the time interval it represents, the paleogeography during its development, its tectonic significance, its regional uranium potential, and its possible significance to uranium districts in other states cannot be satisfactorily answered from data collected during this project. The first phase of future work concerning the Paleocene (?) paleosol will be to reconnoiter the early Tertiary basins in southern New Mexico shown on Figure 5 and determine the present distribution of the paleosol. Once this is determined, detailed topical studies in particularly revealing areas may be undertaken. The author recognizes the vastness of these problems and asks for comments

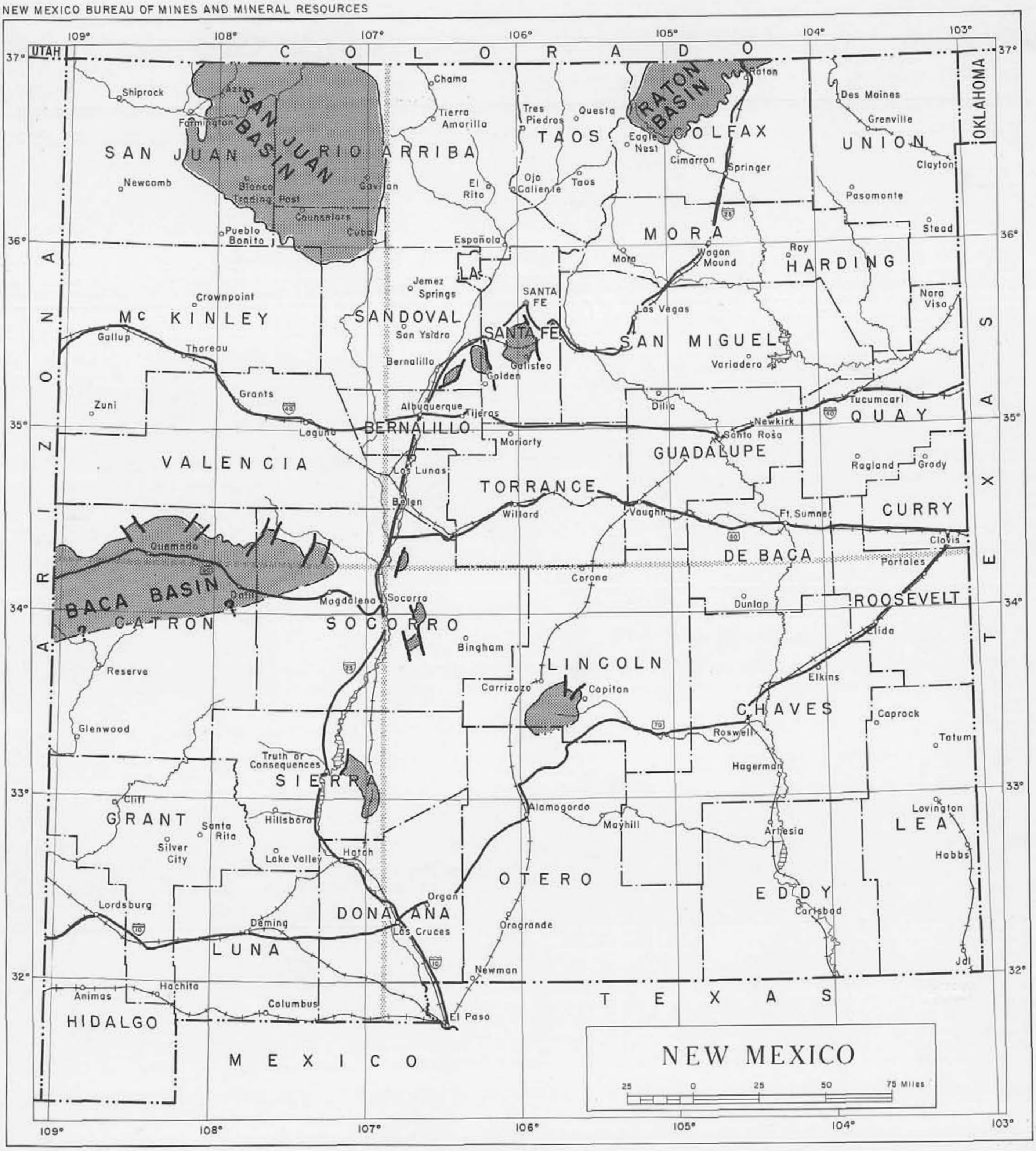


Figure 5 - Erosional remnants of early Tertiary basins (shaded) in New Mexico where a Paleocene(?) paleosol, which may contain uranium deposits, may be preserved. Paleosol may be masked by contemporaneous sedimentation in the San Juan and Raton basins.

and advice from the readers who may have observed similar ancient weathering profiles (color anomalies) in New Mexico. The author hopes to establish a cooperative effort with the geologists who have spent many seasons studying the favorable areas where the Paleocene (?) paleosol may be preserved (fig. 5). Additional sedimentologic-stratigraphic studies of the Crevasse Canyon Formation are warranted in the Datil area, since it is the host for both uranium and coal deposits. Such studies should be accompanied by detailed geologic mapping in the area.

Finally, the genetic model for the uranium deposits of the Datil Mountains area (Table 2), suggests that similar deposits may be forming today where tropical weathering profiles are being developed on slightly uraniferous rocks (protores). This novice uranium geologist asks: Could such actively forming uranium deposits have gone generally unrecognized because they are not associated with gamma radiation anomalies?

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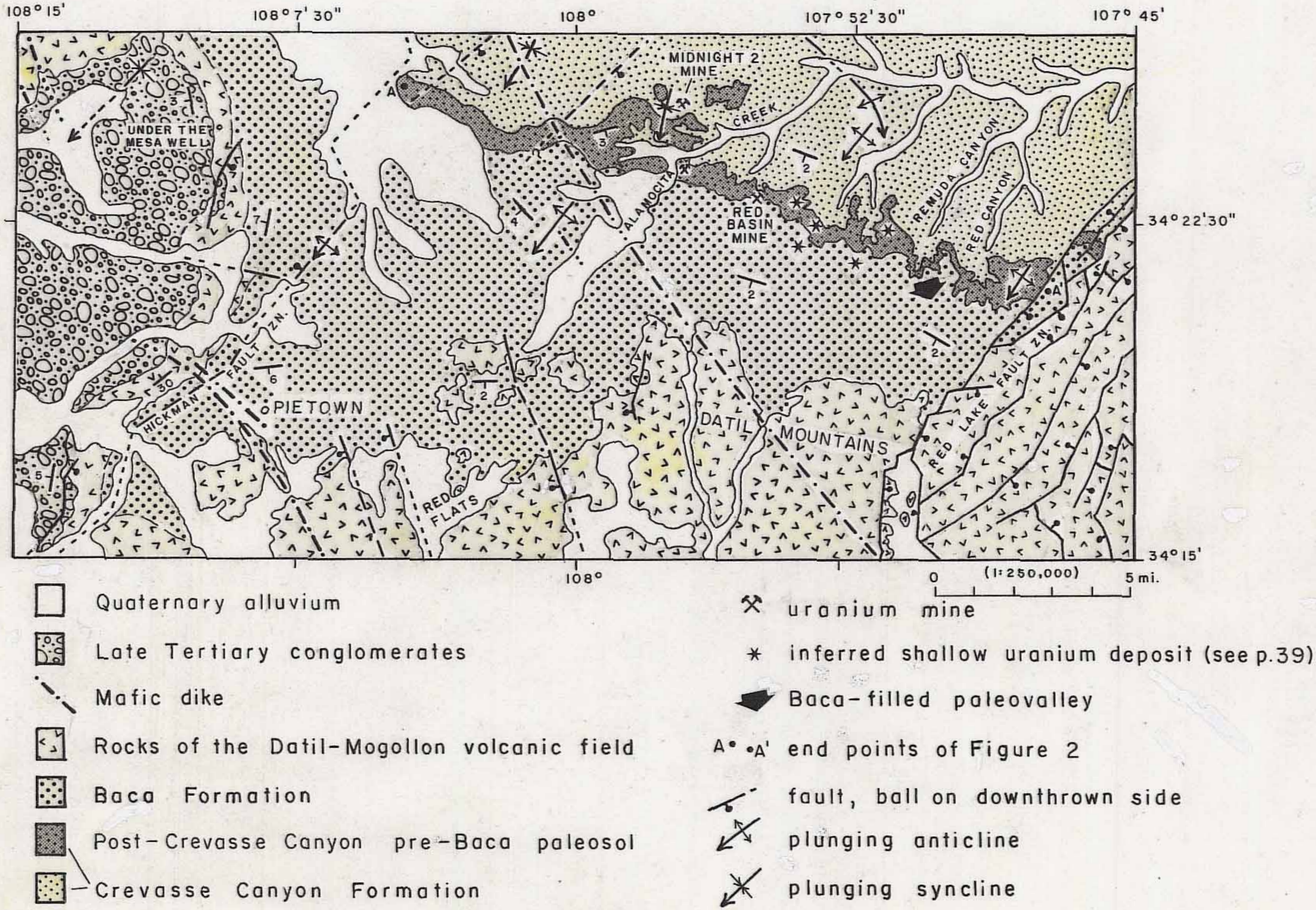

Figure 1 - Generalized geologic map of the Datil Mountains--Pietown area. See Table 1 for description of stratigraphic and rock units.