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Paleokarst, paleosols, cave fillings, and breccias at the Fusselman Dolomite–Percha Shale unconformity, Silver City area, New Mexico

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Abstract

Although the Fusselman Dolomite (Lower Silurian)–Percha Shale (Upper Devonian) contact in the Silver City area has long been recognized as a major unconformity, previous literature describes it only as a planar disconformity. This study describes evidence for paleokarst, paleosols, and pedogenic breccias at the contact. Remnants of a paleokarst are preserved as small sinkholes, solution cavities, linear fissures, and irregular fracture zones filled with terra rosa paleosols and pedogenic breccias. In addition, unusual silicified cave fillings up to 6 ft thick and 50 ft across occur in the upper 10 to 15 ft of the Fusselman.

Paleosol framework grains consist of pebble- and sand-size dolomite clasts and scarce quartz and feldspar; these are set in a matrix of iron-coated dolosilt, dolomicrite, and micrite that has been pedogenically organized into a fabric of peloids, grain cutans, glaebules, and rhizoliths. Four types of breccias are ubiquitous in the upper Fusselman. Type 1 predates the unconformity and consists of fractured host rock. In Type 2, host rock clasts exhibit disintegration and some in situ rounding. Type 3 is paleosol breccia associated with karsting. Type 4 postdates karsting; earlier breccias were refractured and locally silicified. Typical breccias are an evolved mixture of two or more of these types.

Stratigraphy

In west Texas and south New Mexico, the Silurian Fusselman Dolomite includes the entire Llandoverian, Wenlockian, and lower Ludlovian Stages and is disconformably overlain by Middle and Upper Devonian strata (LeMone, 1988). To the north, in the San Andres Mountains and in the Sacramento Mountains where only the lower Ludlovian (Alexandrian) Stage is probably present (Berry and Boucot, 1970; Pray, 1977), and to the west, in the Silver City area where only the middle Llandoverian Stage is present (Berry and Boucot, 1970), the Fusselman becomes an erosionally truncated wedge lying unconformably beneath upper Middle and Upper Devonian strata (Poole et al., 1967; Berry and Boucot, 1970; Pray, 1977) (Fig. 1). In the Franklin Mountains, Harbour (1972) reported Fusselman thicknesses ranging from 320 to 640 ft; LeMone (1992) reported 185 m at the stratotype locale. Pray (1977) reported thicknesses of 70 to 100 ft in the Sacramento Mountains; a maximum of 95 ft is present in the San Andres Mountains (Kottlowski et al., 1956). In the Silver City area thicknesses range widely; Pratt (1967) reported a maximum of 272 ft at Lone Mountain, whereas Pratt and Jones (1961) reported thicknesses as small as 151 ft at Bear Mountain and 100 ft at Georgetown.

The Fusselman in the Silver City area is disconformably overlain by the Upper Devonian Percha Shale, which may include part of the Frasnian as well as the Famennian Stage (Flower, 1965; Fig. 1). The unconformity at the top of the Fusselman is, in fact, part of the Tippecanoe–Kaskaskia sequence unconformity. In spite of early recognition of its profound nature by Paige (1916), this unconformity generally was only briefly and inadequately described in the Silver City literature. Some earlier descriptions are rather better than later ones. Gordon and Graton (1906) described the upper part of a limestone series (mistakenly assigned entirely to the Ordovician but including the Fusselman) as being coarsely brecciated, with spaces between blocks filled with calcareous material. Darton (1917) described the upper part of the formation at nearby Lake Valley as dark colored and containing crevasses filled with red clay. Later studies in the Silver City area did not improve on these descriptions. The contact was variously described as *sharp, planar, accordant*, and *no evidence of angular unconformity* (Pratt and Jones, 1961; Jones et al., 1967; Pratt, 1967), with no attention paid to details. In contrast, Pray (1953) described the contact in the Sacramento Mountains as *smooth* and *covered with reddish brown silica patches*. In the San Andres Mountains the "top of the Fusselman is an undulative, knobby, ridged and channeled, silicified surface of considerable relief" (Kottlowski, 1975). The contact was described in the Franklin Mountains as *locally brecciated* (Pray, 1958) and *of angular nature* and "cut by channels and sinkholes infilled with Devonian strata" (Harbour, 1972). McEvers (1984) reported that the upper Fusselman in the north Franklin Mountains was cut by channels and small sinkholes infilled with solution breccias of Fusselman blocks and clasts set in a dolosilt matrix. The contact's most recent description there by Colleary ☞

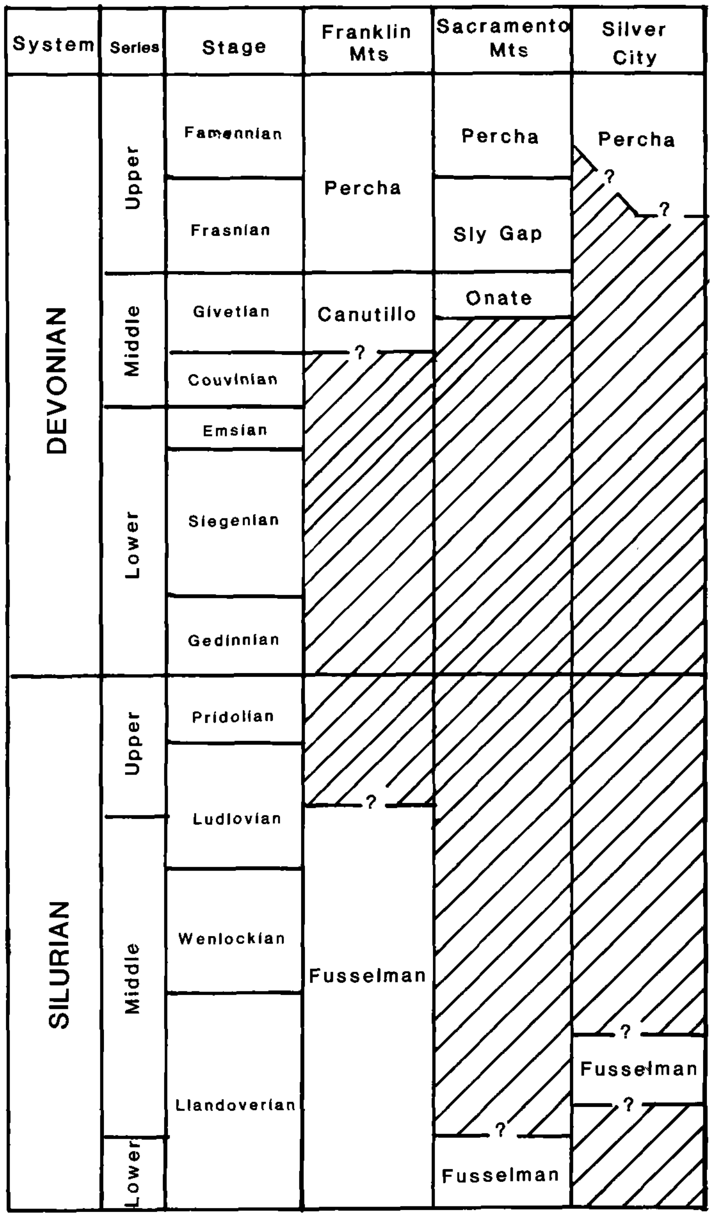

FIGURE 1—Correlation chart of Silurian and Devonian strata in west Texas, south New Mexico, and southwest New Mexico. Compiled and adapted from Kottlowski (1958), Flower (1965), Poole et al. (1967), Berry and Boucot (1970), Pray (1977), and LeMone (1988).

et al. (1992) agrees almost exactly with features described in the Silver City area by Young and Bingham (1991) by mentioning sinkholes, breccia-filled solution channels, and preserved terra rosa. However, this report is the first to describe and analyze the unconformity from both an outcrop and a thin-section perspective and focus on the characteristics of the paleosols.

Study area

Silver City is in north Grant County, New Mexico. Structurally, the area is intermediate between the Colorado Plateau and the Basin and Range provinces (Trauger, 1965). To the west of Silver City, Paleozoic strata are exposed along the west edge of the Silver City Range, a faulted, uplifted, northwest–southest-trending, eastward-tilted structural block. To the east of Silver City, Paleozoic strata are exposed along the east flank of the northwest–southeast-trending, westward-tilted Santa Rita block. These two uplifts form the flanks of the broad Pinos Altos syncline, with Silver City on its axis (Trauger, 1965). Four locations near Silver City were used for this study (Fig. 2).

The Fusselman–Percha contact rarely is well exposed in the study area. The nonresistant Percha has been stripped back and exposes a gentle 7° dip-slope surface on the underlying Fusselman. Typically, the contact itself is covered or obscured by soil or alluvium/colluvium. Exposure of the contact and the Fusselman is also hampered by generally poor quality dip-slope exposures. Luckily, karst and paleosol features so characteristic of the unconformity are also present in the upper few feet of the Fusselman and are generally well exposed.

Paleokarst and paleosol features

Exposures of the Fusselman Dolomite typically exhibit a light-to-dark pink-gray, pitted, vuggy surface. Exposures along the Fusselman–Percha contact and in the upper 15 ft of the formation also exhibit numerous fissures and cavities filled with red-to-maroon breccias and finer-grained material, here interpreted as terra-rosa-like paleosols. The major distinction between these breccias and paleosols is largely one of dominant clast size; the breccias contain many pebble-size host-rock clasts as long as 3 or 4 inches, whereas the paleosols contain mostly granule to coarse sand-size clasts. Otherwise, their petrographies are similar.

Linear fissures typically are up to 1 ft wide and range up to 10 ft long; depths are more difficult to judge, but appear to be as much as 6 ft. Much more complex fissure zones also occur; these are formed by an intricate network of irregular, intersecting fissures that individually are a few inches wide and only a foot or so long. These zones can reach depths of 3 to 7 ft and have the broad shape of inverted cones.

Some fissures and their associated breccias predate the unconformity, although some were modified later by karsting and pedogenesis. Other fissures are more directly related to karsting and to soil development as erosion progressed. These are filled with pedogenic breccias and/or paleosols. Several generations of fissures, breccias, and paleosols may occur in the same complex fissure zone (Fig. 3).

Cavities of solution origin, essentially small sinkholes, generally are semicircular and range from 1 ft to several feet in diameter; depths to 3 ft have been measured. Like their fissure counterparts, these cavities too are filled with pedogenic breccias and/or paleosols. Locally, some fillings are more resistant than the host rock and occur on the outcrop as relict spheroidal bodies with positive relief.

Pebble and granule clasts in the breccias and paleosols are composed of medium to finely crystalline, dully to brightly cathodoluminescent dolomite clearly derived from the Fusselman. Many breccia clasts show both in situ derivation from the host rock and rounding resulting from in situ disintegration and/or dissolution. Some clasts exhibit corrosion and/or a leached, bleached rind around their exteriors. Internal fractures that do not extend into the adjacent matrix indicate that those clasts were in a stage of early disintegration prior to matrix lithification, and these breccias thus are pedogenic (Fig. 4).

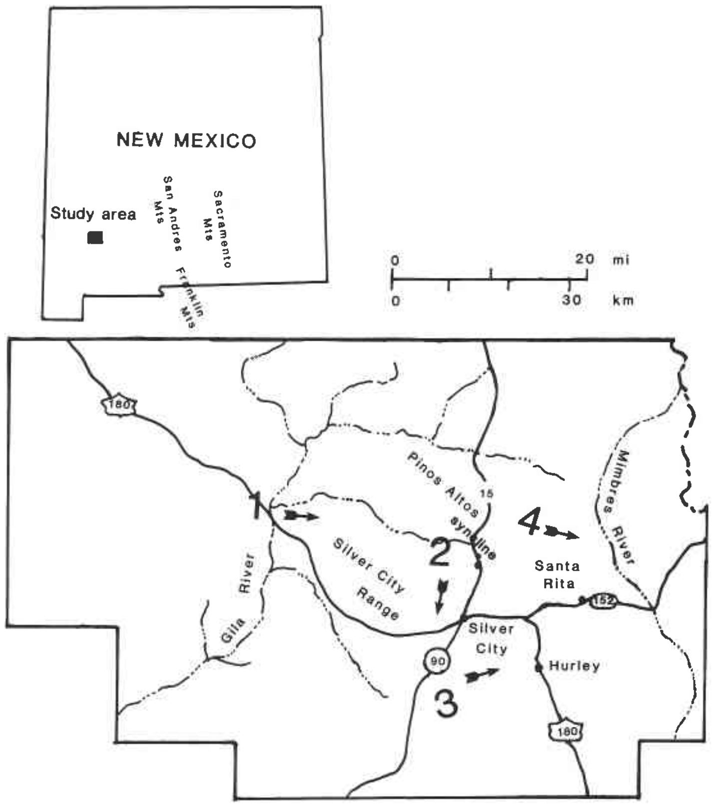

FIGURE 2—Study area and sample locales. **1**, Bear Mountain; **2**, Chloride Flat; **3**, Lone Mountain; **4**, Georgetown. Adapted from Trauger (1965).

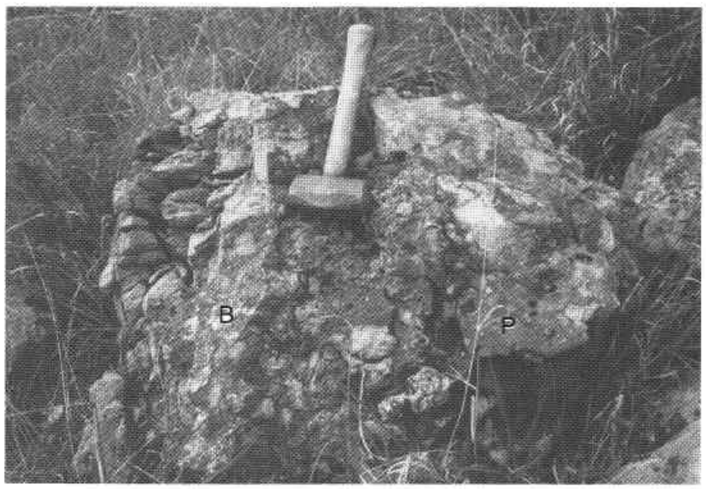

FIGURE 3—Block of upper Fusselman Dolomite showing complex fracture system with two generations of brecciation and paleosol formation. **B** is an older pedogenic breccia; **P** is a younger terra-rosa-like paleosol. Hammer handle is 8 inches long.

Some sand and silt grains are composed of detrital Fusselman Dolomite; the smaller silt grains commonly are euhedral-to-subhedral dolomite crystals that, although broken, exactly match the crystal size of the host rock. The author here refers to these grains as *crystal silt*, although the term is used differently than by Dunham (1969). Thus these grains constitute a matrix of recognizable crystals, the *cystic plasmic fabric* of Brewer (1964), a typical characteristic of some paleosols (Wright and Wilson, 1987).

The red-to-maroon matrix of the pedogenic breccias and the finer-grained material that fills fissures and cavities contain features and structures that, in combination, suggest a pedogenic origin, although no single feature is exclusively pedogenic in nature.

Peloids—Peloids are sand- to coarse-silt-size, ovular to elliptical aggregates of microcrystalline material that occur in many environments and are formed variously by bacterial precipitation, algal encrustation and boring, fecal excretion, and pedogenic/diagenetic processes. Peloids have been well documented in paleosols (Brewer, 1964; Harrison and Steinen, 1978; Esteban and Klappa, 1983; Wright and Wilson, 1987). Fusselman breccias and cavity fillings contain abundant small (0.20 mm) micritic peloids (Fig. 5). Given the context of their occurrence, it is likely these peloids are pedogenic. Although some Fusselman host-rock facies are peloidal, those peloids are now only indistinctly preserved in the dolomite. The paleosol peloids are too well defined to have originated simply by disintegration of the host rock and are composed of calcite, not dolomite. Many are coated with iron oxide as a result of mobilization of *soil plasma* (the relatively unstable, soluble fraction no greater than colloidal size that is not bound up in framework grains) and a release and progressive oxidation and hydration of iron—the *rubification* of Buol et al. (1980) and Duchafour (1982).

Glaebules—Glaebules are lumpy, nodular or concretionary grains, usually with multiple coatings, that represent a concentration of soil plasma. Such grains are common in paleosols (Brewer, 1964; Esteban and Klappa, 1983; Ettensohn et al., 1988; Goldstein, 1988). Glaebules in Fusselman paleosols have multiple micrite coatings around fragmental dolomite cores or around lumps of micritic peloids; many have opaque coatings of iron oxide as well (Fig. 5). These glaebules typically range from 0.5 to 2.0 mm in size.

Grain cutans—Cutans are mineral coatings on grains or lining cavities resulting from mobilization and concentration of soil plasma (Brewer, 1964; Walls et al., 1975; Harrison and Steinen, 1978; Ettensohn et al., 1988). Grain cutans in Fusselman paleosols have detrital dolomite or peloids at the cores and usually single-layer coatings of micrite and/or iron oxide (Fig. 5). Grain diameters are essentially the same as small glaebules.

Crystallaria—Crystallaria is pore- or cavity-filling cement (Brewer, 1964). It occurs as two modes in Fusselman paleosols: (a) a fine-grained (0.10 mm) pervasive, nonluminescent calcispar cement that binds framework grains (Fig. 5) and (b) *pedotuble structures* (Retallack, 1988) filled with nonluminescent and generally mosaic calcispar (Fig. 6). Some pedotubles show a two-stage cementation: an earlier palisade rim cement and a later mosaic cement. In cross section, these structures occur as elipsoidal cavities up to 2 mm in diameter and as irregular, tubular cavities up to several mm in length. Some cavities contain luminescent micritic cores; all contain nonluminescent calcispar cement. Shape, fabric, geometry, and context seem to best match descriptions of fossil root cavities or *rhizoliths* of many workers (Walls et al., 1975; Harrison and Steinen, 1978; Wright and Wilson, 1987; Ettensohn et al., 1988; Retallack, 1988; Wright et al., 1988). These cavities mostly occur singly; a few form the well-defined network of irregular pores separated by micrite walls commonly refered to as *alveolar texture* (Esteban and Klappa, 1983; Wright, 1986). The author has recently examined root-formed pedotubles in Pleistocene paleosols that match these Devonian counterparts in all key respects (Young, 1993).

Pedotubles larger in size than these very small cavities are not apparent; rather than being fossil roots per se, they may be fossil *rhizoids*, rootlet-like projections off the rhizomes of primitive vascular plants typical of the Silurian–Devonian flora (Banks, 1970). In either case, fissures and cavities in the upper Fusselman appear to have contained soils capable of supporting primitive vascular plants.

The nonluminescent nature of all cystallaria might indicate precipitation in a highly oxic environment, perhaps associated with soil diagenesis (Platt, 1989). However, a great deal of caution ought to be exercised in any environmental interpretation based solely upon cathodoluminescent properties of cement (Machal and Burton, 1991).

Terrigenous debris—Framework grains obviously derived from extraformational sources are not plentiful in Fusselman paleosols,

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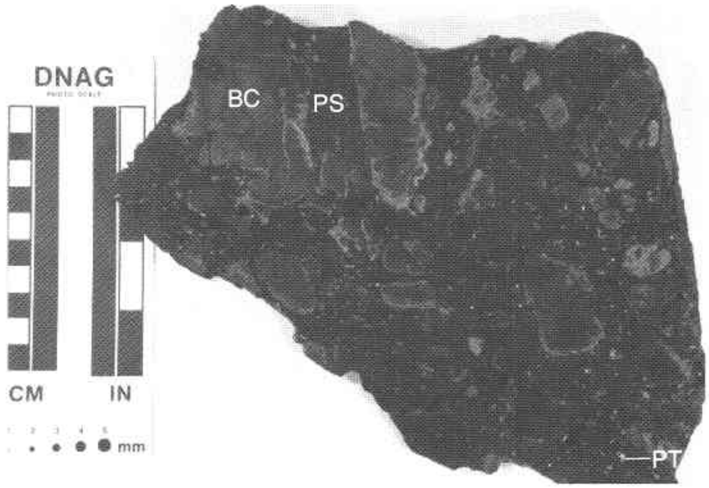

FIGURE 4—Slabbed surface of cavity-fill breccia from small sinkhole. The dark matrix is a terra-rosa-like paleosol (**PS**); the breccia clasts (**BC**) with corroded and leached edges are Fusselman host rock. Pedogenic fractures in clasts do not extend into matrix. The small white spots are pedotubles (**PT**).

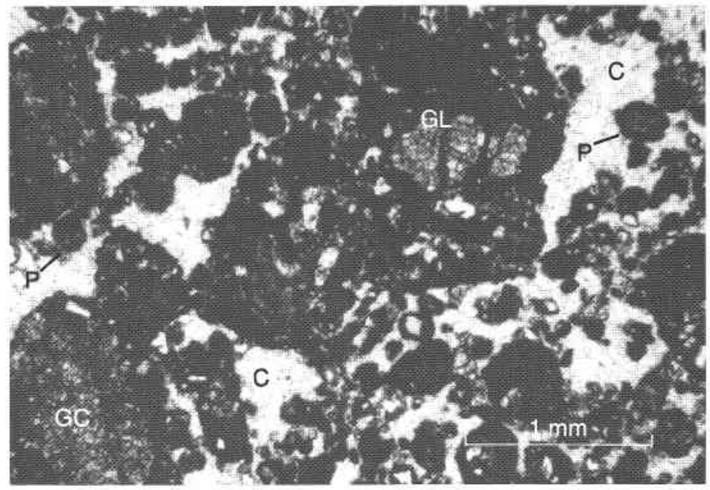

FIGURE 5—Photomicrograph of terra-rosa-like paleosol that typically fills cavities and fissures in the upper Fusselman. Note coated dolomite clast or grain cutan (**GC**), concretionary grain or glaebule (**GL**), peloids (**P**), and calcispar cement (**C**). Plane light. Bar is 1.0 mm.

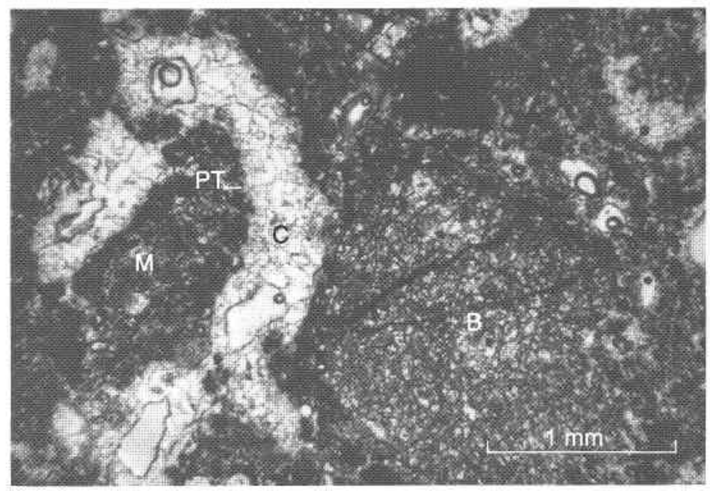

FIGURE 6—Photomicrograph of breccia/paleosol fissure filling with dolomite breccia clast (**B**) in a peloidal-crystal silt matrix (**M**) and pedotuble (**PT**) cemented by calcispar (**C**). Plane light. Bar is 1.0 mm.

FIGURE 7—Silicified cave filling (**C**) at Lone Mountain, 6 ft thick and at least 7 ft in diameter, in contact (arrow) with upper Fusselman host rock (**FHR**). **BZ** is an underlying brecciated fracture zone. Cave roof is missing.

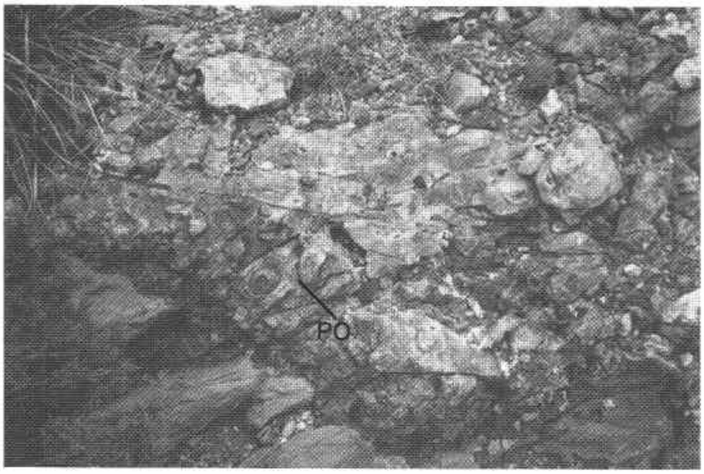

FIGURE 8—Oblique outcrop view of 3-ft-thick silicified cave filling at Lone Mountain. Note pisolite-like structures (**PO**). Cave roof is partly intact.

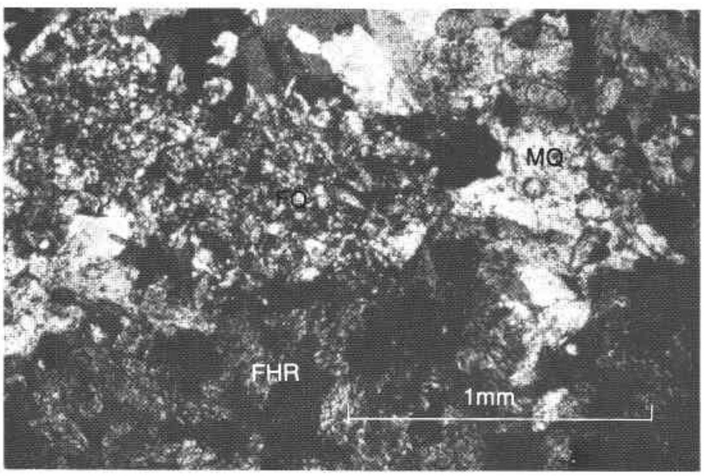

FIGURE 9—Photomicrograph of contact between Fusselman host rock (**FHR**) and cave filling replaced by mosaic megaquartz (**MQ**). Note clast-like relict(?) of finer-grained quartz (**FQ**). Crossed nicols. Bar is 1.0 mm.

but their presence is significant. Grain types include angular to rounded monocrystalline and polycrystalline quartz, angular to well-rounded vein quartz, and vacuolized potash feldspar. There are no sandstone beds in the Fusselman. A possible source of this detritus is Precambrian granitic rocks at the base of the stratigraphic section now exposed along the Silver City Range. Well-rounded quartz may have come from the arkosic Cambro(?)–Ordovician Bliss Sandstone, which immediately overlies the Precambrian and is an alternative source for polycrystalline quartz and potash feldspar. At present, this terrigenous material appears limited to Fusselman exposures along the Silver City Range; no such debris has been noted in admittedly fewer samples from the Georgetown locale. The scarcity of this detritus (nowhere does it attain the status of a sandstone) suggests that the source area was distal from outcrops sampled for this study. But whatever and wherever its source, this debris indicates exposure and erosion of pre-Fusselman rocks during creation of the unconformity and is consistent with the pedogenic origin proposed for cavity and fissure fillings in the Fusselman.

A final characteristic of these paleosols is noteworthy: a virtual lack of any clay. None of the samples examined contain clays in any amount higher than the detection limits of the x-ray diffractometer. A lack of clay is not, however, unknown or uncommon in terra-rosa-like paleosols (Wright and Wilson, 1987).

Silicified cave fillings

Well-exposed large sinkholes related to the unconformity are rare in the Fusselman. Rarer still, but of great significance, are relicts of isolated caves that apparently developed during post-Fusselman karsting (Young, 1992). Field work so far has found these remnants only near Bear Mountain and at Lone Mountain (Fig. 2, locations 1 and 3 respectively).

These former caves are now preserved as silicified cave fillings in the upper 10 to 15 ft of the Fusselman. In one mode of occurrence, the surrounding host rock, including the cave roof, has been mostly eroded away, and the more resistant fillings stand out as isolated knobs rising 3 to 6 ft above the ground surface. These knobs define small, apparently semicircular caves whose depths ranged from 3 to 6 ft and diameters ranged from 6 to 10 ft (Fig. 7). It is possible that these caves were once of greater lateral extent, like the relicts of the second mode of occurrence. In this second mode, silicified fillings in the host rock are lenslike bodies up to 3 ft thick and as much as 50 ft long. They generally retain some of the cave roof (up to 6 to 10 ft thick), but lateral extent can only be seen in one direction (Fig. 8).

The fillings consist of stacked gray-white quartzose layers or beds generally parallel to cave floors. Layers range from 1 to 2 inches thick and are somewhat uneven. Relict bedding planes are distinct and locally stylolitic. The floors of caves form surfaces with a macrorelief up to 1 inch and microrelief of less than 1 mm. Besides this bedding, which is here assumed to be a relict of the original cave-filling fabric, distorted pisolite-like bodies 1 to 4 inches in diameter with a banded substructure occur locally (Fig. 8). There is a fair outcrop-scale resemblance to laminated cave-sediment fills and cave pearls (pisolites) described by many workers; an especially striking and possible analog noted by the author is figured by Esteban and Klappa (1983, p. 17).

It appears that these caves originated atop pre-existing vertical fracture/fissure zones already filled with breccias and terra-rosa-like paleosols (Fig. 7). These fissures appear to have served as local loci for subsequent cave formation. It is possible that some of the material lodged in these underlying fissures was originally present in the overlying caves.

The contact between the cave fillings and the host rock is sharp; virtually no silicification of the host rock has occurred across this contact (Fig. 9). Exceptions are where siliceous solutions penetrated porous fracture/fissure zones beneath the caves; here, minor to wholesale replacement of breccia, paleosol, and host-rock fabric has occurred. Replacement of the original fabric of the cave fillings is complete. Replacement in all cases is by a mosaic of 0.15 to 0.50 mm subhedral to anhedral megaquartz (Figs. 9, 10). The basal layer of one filling contains clast-like patches of finer-grained 0.05 to 0.30 mm quartz (Fig. 9); these may be relicts of an originally clastic fabric. The pisolite-like bodies show a fabric of alternating bands 0.25 to 0.50 mm thick composed of coarse- and finer-grained megaquartz. Except for pisolites, possible clasts, odd patches of non-calcite carbonate (Fig. 10), and tiny calcite rhombs enclosed in quartz grains, nothing remains of the original fabric. No clay has been detected in these fillings. Thus no direct petrographic comparison between these and more conventional cave fillings is possible.

The selectivity of such an extensive replacement is somewhat puzzling but must be viewed in the framework of a proposed mechanism. The most likely source of replacement is hydrothermal fluids associated with Laramide intrusion and mineralization of the Silver City area. The upper Fusselman was a natural locus for some of this mineralization because of its typically highly porous nature (breccias, cavities, fissures, caves) and because the overlying Percha Shale formed an almost impermeable seal, trapping mineralizing fluids rising from below (Hernon et al., 1965). Silicification of the cave deposits was only part of a broader spectrum of silica replacement that also affected the matrix of breccias and paleosols and caused deposition of megaquartz in late-formed, open fractures that postdate the unconformity. Additionally, local silicification affected a pentamerid brachiopod biostrome (probably *Virgiana* according to Berry and Boucot [1970]) that occurs sporadically at the top of the formation; not only shells but the surrounding host rock have been partially to totally replaced by megaquartz in a manner identical to that seen in the cave fillings.

Breccias

Breccias are a common feature in the Fusselman. Some are fault related and are not considered in this report. Aside from intraclastic layers, there are no intraformational detrital breccias or conglomerates. All other breccias are confined to fracture zones or to cavity and fissure fillings. Four distinct, sequential types (or stages) are recognized.

Type 1 breccias are the oldest, predate karsting, and occur along fracture zones. The type occurs throughout the formation but is perhaps more abundant in the upper Fusselman. The host rock is highly fractured into cm-size angular clasts that locally retain a jig-saw-puzzle fit with adjacent clasts and host rock. The clasts are cemented by coarse (up to 1.0 mm), euhedral, zoned, and generally luminescent dolospar (Fig. 11). Fracturing is interpreted as tectonic in origin, related possibly to a pre-unconformity episode of reduction in confining pressure (Sieverding and Harris, 1991). Locally, some Type 1 breccias served as sites of refracturing and subsequent evolved breccia development.

Type 2 breccias represent an intial stage of pedogenic brecciation and paleosol formation (Fig. 12). This type occurs within some cavities and fissures, where the clasts of host rock show some displacement, in situ rounding, and in situ disintegration into sand- and silt-size fragments (*crystal silt*). The matrix consists of a mixture of crystal silt and iron oxide-stained dolomicrite. In outcrop, these breccias typically are red to pink.

Type 3 breccias are clearly associated with karsting and paleosols. Host-rock clasts are rounded and corroded; some show bleached exterior rinds; all are dispersed in a terra-rosa-like matrix of iron oxide-stained dolomicrite, crystal silt, peloids, grain cutans, and glaebules, cemented by nonluminescent calcispar (Figs. 4, 6, 13). Locally, the matrix, but never clasts, is penetrated by pedotubles. In outcrop, these breccias are typically maroon.

Type 4 breccias postdate the unconformity. Earlier breccias were locally refractured (new fractures cut across older clasts and matrix) and recemented by nonluminescent calcispar and/or megaquartz (Fig. 14). In some instances total replacement of breccia fabric by megaquartz has occurred. The source of silicification is believed to be the same hydrothermal mineralization responsible for cave-filling replacement.

Evolved breccias are composites of two or more breccia types where a progression of breccia development from one type to another is apparent. Some show relicts of all four stages. Evolved breccia is the most common type observed in the upper Fusselman.

Summary

After burial and lithification, the Fusselman was ubiquitously fractured, producing widespread Type 1 brecciation. It is not clear

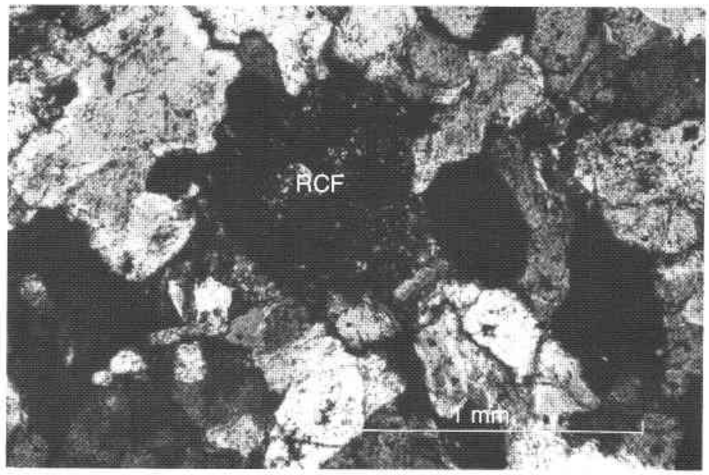

FIGURE 10—Relict carbonate fabric (**RCF**) in megaquartz mosaic in cave filling. Crossed nicols. Bar is 1.0 mm.

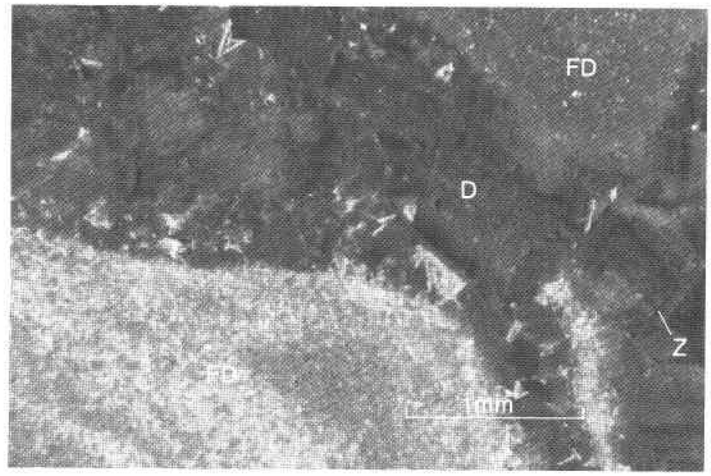

FIGURE 11—Photomicrograph of Type 1 breccia under cathodoluminescence. Moderately to brightly luminescent Fusselman dolomite clasts (**FD**) are cemented by coarse, euhedral, faintly luminescent dolospar (**D**). Zoning in dolospar can be seen at **Z**. Bar is 1.0 mm.

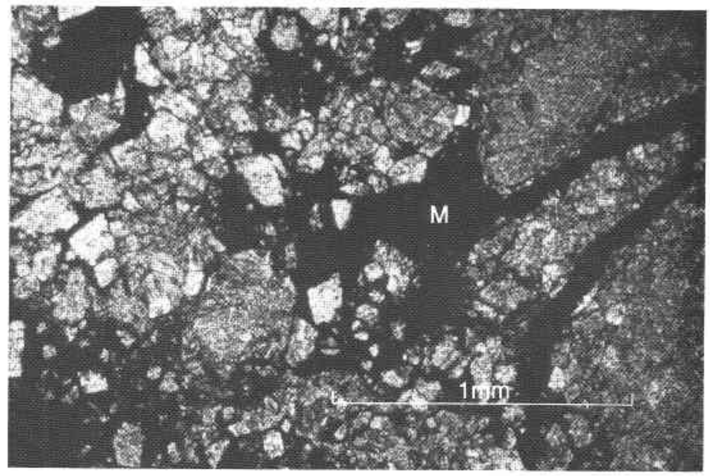

FIGURE 12—Photomicrograph of Type 2 breccia showing in situ rounding and disintegration of dolomite clasts. Matrix (**M**) is iron oxide-stained dolomicrite and dolosiltite. Plane light. Bar is 1.0 mm.

if cementation of these fractures occurred in conjunction with or succeeded dolomitization of the host rock. Both dolomites show dull to moderately bright luminescence; however, cements show cyclic zoning (Machal and Burton, 1991) and a general resemblance to the OBC cements described by Meyers (1991), whereas host-rock dolomite does not. The oldest part of some cements ☞

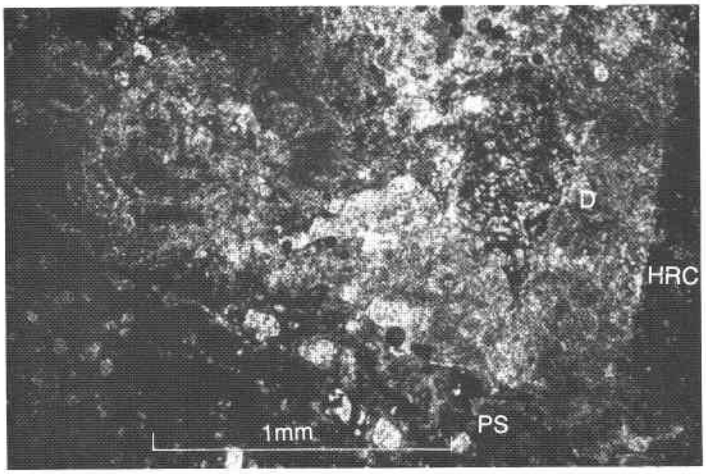

FIGURE 13—Photomicrograph of Type 3 breccia with terra-rosa-like paleosol matrix (**PS**). Type 1 dolospar cement (**D**) is still attached to host rock clast (**HRC**). Plane light. Bar is 1.0 mm.

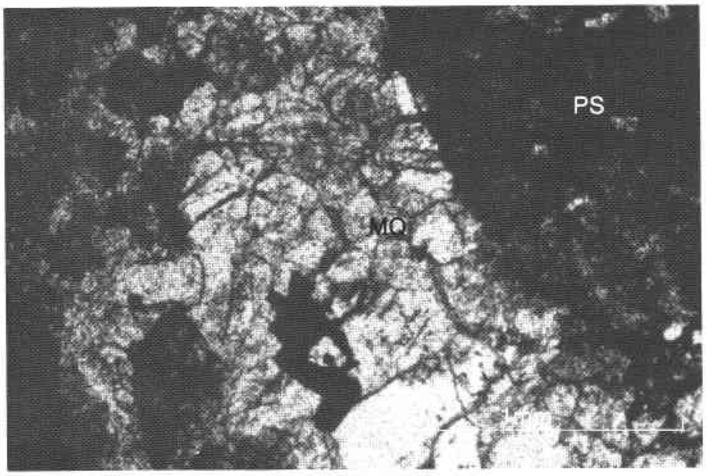

FIGURE 14—Photomicrograph of Type 4 breccia. A Type 3 has been refractured and recemented by megaquartz (**MQ**). Older Type 3 paleosol matrix (**PS**) can be seen on the right. Plane light. Bar is 1.0 mm.

has a luminescence that differs from the clast to which it is attached, suggesting that dolomitization of the host rock and precipitation of dolospar cements were separate diagenetic events.

Uplift and surface exposure of the Fusselman prior to Late Devonian time began the karsting and pedogenesis associated with the unconformity. Type 1 breccias served as preferred sites for further fracturing, fissuring, and formation of Types 2 and 3 breccias and paleosols. Linear fractures evolved into liner fissure fillings. Where fracture patterns were less linear and even cone shaped, more complex fissure-filled networks and sinkholes formed. Localized caves of modest dimensions developed in the upper few feet of the formation at sites of earlier brecciation and paleosols. Smaller circular sinkholes/cavity fillings up to a foot in size do not appear to be as site-controlled and may be random solution pits. Terra-rosa-like paleosols in fissures and cavities apparently supported a community of primitive land plants that lacked large root systems. By analogy with modern terra rosa soils, Fusselman paleosols may have developed under a moist, subtropical/Mediterranean climate (Duchafour, 1982; Ettensohn et al., 1988). The final event affecting the unconformity was Laramide hydrothermal mineralization along and beneath the buried surface. Pre-existing sites of older brecciation were refractured and recemented or replaced by calcite and/or quartz. The same mineralization obliterated the fabric of the layered cave fillings, making it impossible to determine their original nature.

Dolomitization of the Fusselman host rock preceded pedogenic brecciation, paleosol formation, and karsting. Paleosols and Type 3 breccias are cemented by calcite, not dolomite. If dolomitization postdated these, then replacement of the calcite cement should have occurred. Type 4 breccias, which postdate paleosols and all other breccias, are cemented by calcite and quartz, not dolomite. Therefore, dolomitization of the Fusselman cannot be the result of the Laramide mineralization.

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New Mexico Geological Society

1995 Fall Field Conference: Santa Fe
Announcement and call for papers

The New Mexico Geological Society will convene in Santa Fe on September 27, 1995 for its annual three-day fall field conference. Santa Fe is in a dramatic and diverse geologic setting, in the borderland between the Rio Grande rift and the southern Sangre de Cristo Mountains. The conference will focus on the Proterozoic to present tectonic development of basins and highlands and their complex margins. Other topics will include mineral resources related to Tertiary volcanism, the environmental geology of the Santa Fe area, geophysical investigations of the Española Basin, Precambrian geology of the Sangre de Cristo and Sandia Mountains, Tertiary basin stratigraphy, Quaternary history of the Rio Chama and Rio Grande, paleontology, sedimentology, geologic hazards such as seismicity and collapsible soils, and industrial rock and mineral resources. The trip will not explore the geology of the Jemez Mountains, as that will be the focus of the 1996 trip.

Day 1 will tour northward from Santa Fe into the southern Española Basin, along US–84 through Tesuque and Española to Abiquiu. Highlights will include the structure of the southern Española Basin, mountain-front neotectonics, geophysical investigations along the western rift margin, Santa Fe Group stratigraphy and paleontology, the Abiquiu Formation type section, Quaternary history of the lower Rio Chama, and environmental geology.

Day 2 will skirt the southern end of the Sangre de Cristo Mountains along I–25 to Las Vegas. Highlights will include the southern Picuris–Pecos fault, Early Proterozoic mylonites and plutons of the southern Sangre de Cristo Mountains, Glorieta Mesa, Laramide structures, the Mesozoic section in the Las Vegas sub-basin, and environmental problems along the Pecos River.

Day 3 focuses on the transition zone between the Española Basin and the Albuquerque Basin, south of Santa Fe. Highlights will include Tertiary stratigraphy and gold mineralization in the Ortiz Mountains, deformation and sedimentation associated with Tertiary intrusions, early rift sedimentation, the northern Tijeras fault zone, the turquoise mines of Cerrillos, and structures of the Hagan Basin. We also plan to visit the studio of famed Native American sculptor Allan Houser.

The guidebook editors are now soliciting papers and minipapers for the field conference guidebook. Guidebooks generally cover a wide range of topics in earth science and cultural history. Guidebook papers will be due in **February 1995**. If you plan to contribute, or know of some work that should be included, please contact Paul Bauer, NM Bureau of Mines and Mineral Resources, Socorro, NM 87801; phone (505) 835-5106; fax (505) 835-6333; email: bauer@jupiter.nmt.edu.

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