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New Mexico Geology, v. 9, n. 3 pp. 50-54, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v9n3.50

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Introduction

The Datil Group, formerly called the Spears Formation, comprises a series of volcaniclastic rocks, lava flows, and ash-flow tuffs that crops out in a broad, west-trending swath of discontinuous exposures in west-central New Mexico. The Datil Group is the oldest unit in the northern Mogollon–Datil volcanic field, and ranges in thickness from more than 1 km to about 300 m where it onlaps late Laramide uplifts. This report summarizes part of a doctoral dissertation on the Datil Group (Cather, 1986) and incorporates 15 new radiometric dates by McIntosh et al. (1986), McIntosh (in progress), C. E. Chapin (unpublished), and Cather (1986). To facilitate discussion of various Datil Group exposures within the study area, we have divided the outcrop belt into geographic segments (Fig 1).

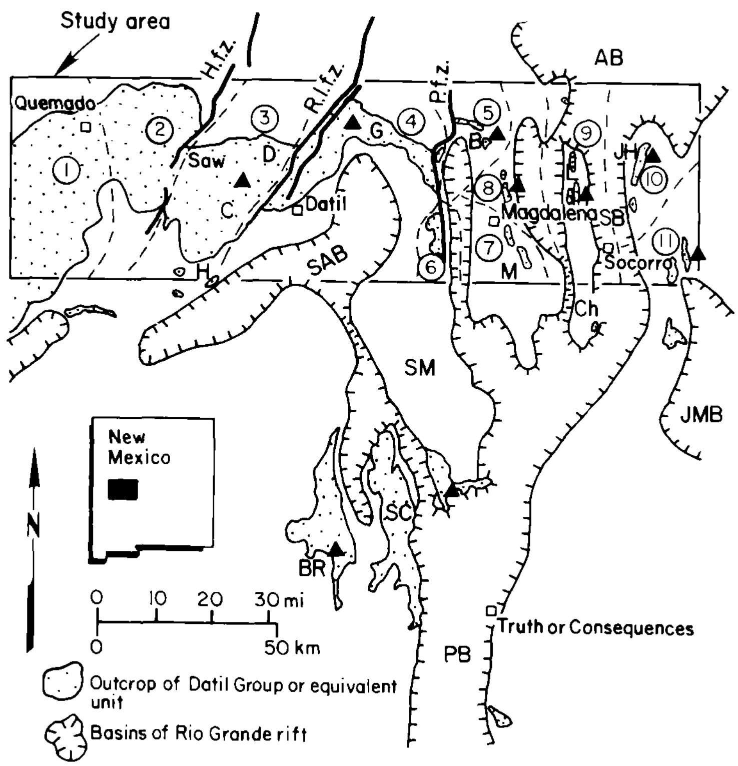

FIGURE 1—Location map showing study area, outcrops of Datil Group and equivalent units, basins of Rio Grande rift, and selected structural and geomorphic features. *Intrabasin fault zones* active during Datil time are shown by heavy lines: **H.f.z.**, Hickman fault zone; **R.l.f.z.**, Red Lake fault zone; **P.f.z.**, Puertecito fault zone. *Segments of outcrop belt* are divided by fine dashed lines and are indicated by encircled numbers: **1**, Quemado; **2**, Alegros Mountain area; **3**, Datil Mountains–Crosby Mountains; **4**, Gallinas Mountains area; **5**, northern Bear Mountains; **6**, Tres Montosas area; **7**, Magdalena Mountains; **8**, Nipple Mountain–Granite Mountain; **9**, Lemitar Mountains; **10**, Joyita Hills; **11**, northern Jornada del Muerto. *Geomorphic features*: **H**, Horse Mountain; **SAB**, San Agustin Basin; **D**, Datil Mountains; **C**, Crosby Mountains; **Saw**, Sawtooth Mountains; **G**, Gallinas Mountains; **B**, Bear Mountains; **M**, Magdalena Mountains; **L**, Lemitar Mountains; **Ch**, Chupadera Mountains; **JH**, Joyita Hills; **SM**, San Mateo Mountains; **SC**, Sierra Cuchillo; **BR**, Black Range; **SB**, Socorro Basin; **AB**, Albuquerque Basin; **JMB**, Jornada del Muerto Basin; **PB**, Palomas Basin. *Measured and sampled sections* are denoted by solid triangles, ▲ (Cather, 1986). Base map modified from New Mexico Geological Society (1982).

Stratigraphy and contacts

The term Datil Formation was coined by Winchester (1920), but its usage has since evolved considerably (see, for example, Elston, 1976; Cather, 1986). In this report, we employ the nomenclature of Osburn and Chapin (1983), who restrict usage of the Datil Group to the volcanic and volcaniclastic rocks that occur *below* Hells Mesa Tuff. In addition, we divide the Datil Group into two informal units, the lower Datil and the upper Datil (Fig. 2).

The lower Datil is dominated by andesitic volcaniclastic rocks that are characterized by phenocrystic plagioclase, amphibole, and titanomagnetite (± biotite). Silica content in Datil andesites typically ranges from 58 to 64 wt. percent. Throughout most of the northern Mogollon–Datil volcanic field, the lower Datil Group overlies late Laramide, synorogenic red beds of the Eocene Baca Formation. The contact between these units is defined as the first up-section occurrence of megascopic volcanic detritus (Cather, 1980), and is typically marked by a pronounced change from the red colors of the Baca Formation to the grays, buffs, purples, and reddish-grays of the Datil Group. The Baca–Datil contact is everywhere conformable and gradational, except where early Datil fluvial scouring has created local, apparently sharp contacts. Where deposited upon late Laramide uplifts, the Datil Group typically overlies strata of Pennsylvanian or Permian age with angular disconformity; such contact relations are exposed in the Lemitar Mountains, Chupadera Mountains, southern San Mateo Mountains, Magdalena Mountains, Black Range, and at Horse Mountain (Fig. 1).

In nearly all exposures that were examined, non-volcanic detritus identical to that of the Baca Formation is present throughout most or all of the lower Datil Group (Fig. 2). This detritus, consisting dominantly of fragments of upper Paleozoic limestone, sandstone, and siltstone with subordinate amounts of Precambrian lithologies, represents the continuation of Baca-style sedimentation during early Datil volcanism and is important because it indicates the persistence of late Laramide positive areas following the onset of volcanism in west-central New Mexico. Abundance of non-volcanic detritus in the lower Datil ranges from individual beds of nearly pure Paleozoic and Precambrian detritus to trace amounts of such lithologies present as scattered clasts in volcaniclastic conglomerates.

The upper Datil Group consists of a fundamentally bimodal suite of basaltic andesite lava flows, rhyodacitic to rhyolitic ash-flow tuffs, and volcaniclastic rocks derived from these lithologies. Basaltic andesites range in silica content from about 52 to 56 wt. percent, and are characterized by phenocrysts of plagioclase, clinopyroxene, and titanomagnetite (± olivine, amphibole). Basaltic andesite lavas are widespread in the upper Datil; composite thickness for such lava flows locally exceeds 150 m (LaRoche, 1981). Four ash-flow tuffs of regional extent occur in the upper Datil Group. Using the terminology of Osburn and Chapin (1983), these are the Datil Well Tuff, Rock House Canyon Tuff, Blue Canyon Tuff, and the tuff of Granite Mountain. Unlike the lower Datil Group, the upper Datil does not contain non-volcanic detritus.

The contact between the lower and upper Datil Group is gradational and typically occurs within the volcaniclastic rocks that underlie the basaltic-andesite lava flows and silicic ash-flow tuffs of the upper Datil (Fig. 2). This contact is defined as the first up-section occurrence of greater than 50% basaltic-andesite detritus. The transition from andesitic to bimodal volcanism, as represented by the lower Datil–upper Datil contact, marked a time of important changes in tectonism, sedimentation, and petrogenesis in west-central New Mexico (Cather, 1986). The upper contact of the Datil Group is placed at the base of the Hells Mesa Tuff (~32 Ma), a thick, regionally extensive ash-flow tuff in the northern Mogollon–Datil field. The

Datil–Hells Mesa contact is commonly concealed by talus due to the cliff-forming nature of the Hells Mesa Tuff. Where exposed, however, the contact is sharp and typically conformable, except where the Hells Mesa Tuff fills local paleovalleys.

During deposition of the Eocene Baca Formation, two intermontane basins (the Baca and Carthage–La Joya basins) and their surrounding uplifts dominated the late Laramide paleogeography of west-central New Mexico (Cather, 1983; Cather and Johnson, 1984, 1986). Late Laramide basin geometries persisted during Datil volcanism, as shown by similarities in facies distribution and paleocurrent azimuths within the Baca Formation and Datil Group (Cather, 1986). Therefore, the terms Baca basin and Carthage–La Joya basin are retained in describing the sedimentary paleoenvironments of the Datil Group. Depositional systems of the Datil Group are identical to and transitional with the fluvial-lacustrine facies tract of the Baca Formation, except in the Gallinas Mountains, Datil Mountains, and Sawtooth Mountains, where debris-flow deposits are a major component of the lower Datil Group (Cather, 1986).

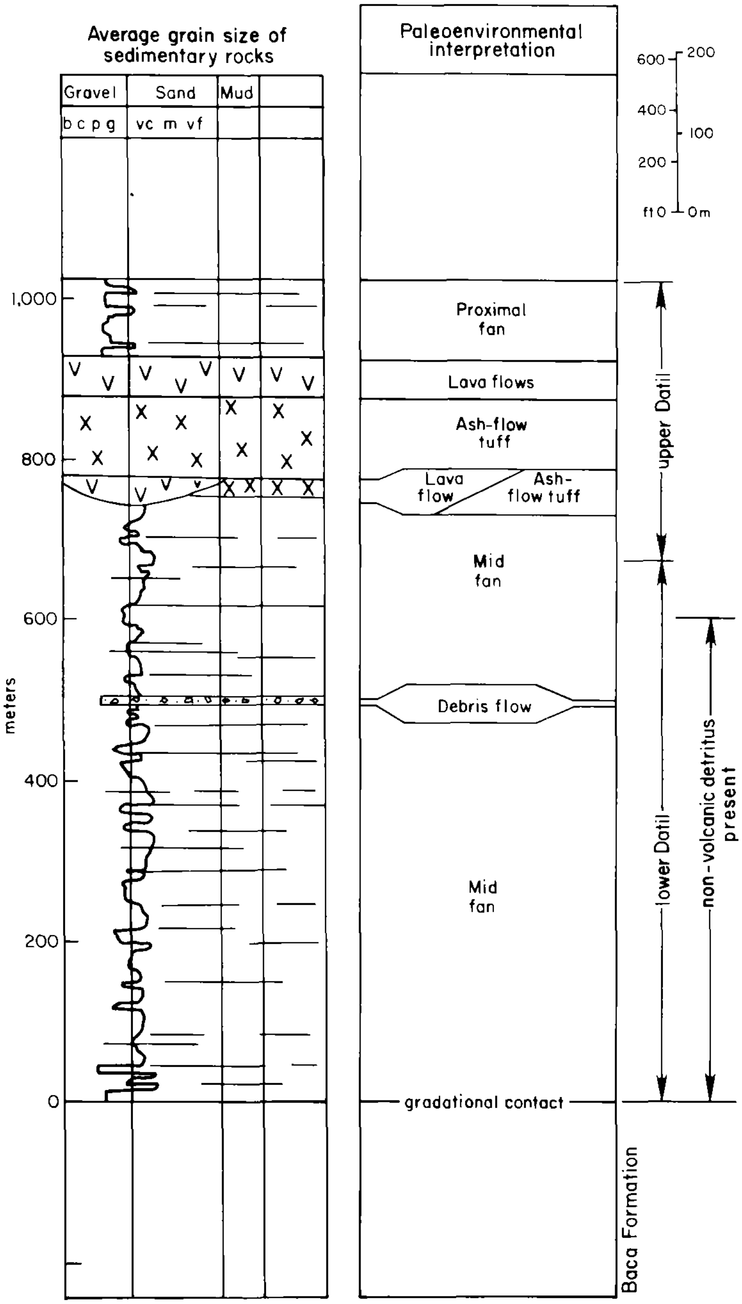

FIGURE 2—Representative stratigraphic section of Datil Group showing informal units and distribution of lithologies. Section measured in northern Jornada del Muerto Basin by S. M. Cather.

Location of eruptive centers

Although dikes of probable late Datil age have been documented in the Joyita Hills (Spradlin, 1976) and the northern Bear Mountains, exposures of Datil Group eruptive centers have not been documented anywhere in the northern Mogollon–Datil volcanic field. However, the distribution of sedimentary facies and paleoflow in Datil volcaniclastic rocks provides important constraints on the location of associated volcanic centers. For example, paleocurrent and facies data strongly suggest that Datil andesite and basaltic andesite eruptive centers were present along what is now the Socorro Basin of the Rio Grande rift. This area coincides with the northern portion of the Laramide Sierra uplift (Cather, 1983; Cather and Johnson, 1984; 1986), which remained topographically positive throughout Datil time.

The majority of volcaniclastic deposits in the Baca basin were derived from the south and southwest (Cather, 1986). Eruptive centers of probable Datil age are present in the western part of the Mogollon–Datil volcanic field (Ratté et al., 1969; J. C. Ratté, written comm. 1987), and may have supplied detritus to the western portion of the study area. The location of source vents for deposits in the central part of the study area is not well constrained because of the lack of Datil-equivalent exposures in the central portion of the Mogollon–Datil volcanic field. However, the similarity of facies distribution and paleoflow between the Baca Formation and Datil Group suggests that Datil eruptive centers were developed on, or near, the southern boundary of the Baca basin (the Laramide Morenci uplift; Cather and Johnson, 1984, 1986). Although its geometry and structural style are poorly understood, the Morenci uplift appears to have undergone mid- and late-Tertiary extension and collapse, to form the San Agustin Basin and its associated grabens to the southwest.

Available data suggest that Datil source vents were developed on, or near, Laramide positive areas in west-central New Mexico. This spatial association is intuitively reasonable because zones of prior Laramide deformation would tend to provide favorable pathways for magma ascent. The location of source vents for Datil Group ash-flow tuffs is unknown; outcrops are too sparse to determine vent locations using thickness and distribution data, and detailed petrofabric studies of flow-direction indicators in these tuffs (e.g., Elston and Smith, 1970) have not yet been attempted.

Age

Radiometric age determinations for the Datil Group range from about 28 to 42 Ma (Fig. 3; Table 1), although a few of the oldest and youngest ages are clearly geologically unreasonable (see remarks in Table 1). Reasonable radiometric ages for the lower Datil (all from clasts in conglomerate) indicate an age range of about 37 to 40 Ma; average ages for ash-flow tuffs in the upper Datil range from about 34 to 36 Ma. Due to inherently poor precision of K/Ar and fission-track dating, ages obtained by these methods can serve only as general guidelines in stratigraphic analysis of the Datil Group. Dating of these rocks by the $^{40}Ar/^{39}Ar$ method (McIntosh et al., 1986; McIntosh, in progress) provides much more useful constraints because of the small relative error of this method (approximately ± 0.15 m.y. for lower Oligocene rocks). The first geologically reasonable date for the Rock House Canyon Tuff has been obtained recently by the $^{40}Ar/^{39}Ar$ method (Table 1; McIntosh, in progress). Previously, this tuff had yielded only three ages, all geologically unreasonable, by the K/Ar method (Fig. 3).

Radiometric dates for the Datil Group have several important implications:

1) Age determinations for the Eocene–Oligocene boundary range from 35.7 ± 0.4 Ma (Montanari et al., 1985) to 36–37 Ma (Prothero et al., 1982; Prothero, 1985; Berggren et al., 1985). Therefore, it appears that most or all of the lower Datil volcaniclastic rocks, in places as much as 680 m thick, are of Eocene age. This interpretation is compatible with Eocene age determinations for correlative(?) early andesitic rocks in south-central New Mexico (Palm Park Formation, Macho Andesite, and the lower, andesitic part of the Rubio Peak Formation), which have yielded K/Ar ages ranging from 36.7 to 51 Ma (Kottlowski et al., 1969; Seager et al., 1975; Marvin and Cole, ☞

1978; Clemons, 1982; Loring and Loring, 1980; Seager et al., 1982) and a vertebrate fossil of Duchesnean age (Lucas, 1983).

2) The transition from fundamentally andesitic to bimodal volcanism in the northern Mogollon–Datil field (as represented by the contact between the lower and upper Datil) approximately coincides with the Eocene–Oligocene boundary (Fig. 3). This is at odds with the previous placement of the Eocene–Oligocene boundary at or near the Baca–Datil contact (Lucas, 1983).

3) Throughout the study area, the lower Datil Group is everywhere thicker than the underlying Baca Formation. Because local basin geometries were similar during Baca and Datil deposition, these thickness relationships indicate that the lower Datil Group is the volumetrically dominant Eocene unit in west-central New Mexico.

4) Stratigraphic and structural data (Cather, 1986) indicate a major transition in lithospheric stress regime in west-central New Mexico accompanied (and probably caused) the change from early Datil andesite to later bimodal volcanism. Radiometric dates from the Datil Group suggest the tectonic transition from waning Laramide shortening to incipient mid-Tertiary extension occurred about 36 Ma—approximately coincident with the Eocene–Oligocene boundary.

No fossils have been reported from any of the Datil Group exposures in the study area. However, the Red Rock Ranch paleoflora from the Placitas Canyon lakebeds (upper Datil equivalent?) in the southern San Mateo Mountains (Farkas, 1969; Axelrod, 1975; Axelrod and Bailey, 1976) shows similarities to the Florissant flora of early Oligocene age (about 34–35 Ma; Epis et al., 1980) in central Colorado. The Placitas Canyon lakebeds are directly overlain by a basaltic andesite flow (Uvas Canyon andesite of Farkas, 1969) that has been dated at 35.1 ± 1.8 Ma by the K/Ar method (Cather, 1986). Fossil mammals from the upper part of the Rubio Peak Formation in the Black Range (Lucas, 1986; Harrison, 1986) are early Oligocene (Chadronian) in age.

Sedimentation rates

Average sedimentation rates can be estimated from the Datil Group section in the western Gallinas Mountains, where four tuffs (Datil Well Tuff, Rock House Canyon Tuff, Blue Canyon Tuff, and Hells Mesa Tuff) are present and have been dated by the precise $^{40}Ar/^{39}Ar$ method. Assuming that the oldest dated clast (39.6 ± 1.5 Ma [K/Ar date]; see Fig. 3 and Table 1) from the basal part of the Gallinas Mountains section is representative of the approximate beginning of volcaniclastic sedimentation, average sedimentation rates for the Datil Group can be estimated (Fig. 4). Datil Group sedimentation rates ranged from about 32 to 177 m/m.y., and may have diminished through time. Episodic deposition of major debris flows may account for high sedimentation rates during early Datil time in the western Gallinas Mountains. Because average sedimentation rates were no doubt strongly influenced by the effects of intrabasin structures on local subsidence (Cather, 1986), sedimentation rates in other areas of the Datil outcrop belt were probably significantly different from those depicted in Fig. 4. Rates of deposition comparable to those of the Datil Group have recently been determined for Plio–Pleistocene sediments in the Mesilla Basin of southern New Mexico (25 to 60 m/m.y.; Vanderhill, 1986; J. W. Hawley, oral comm. 1987).

Summary

Beginning about 40 Ma, andesitic eruptive centers began to develop on or near late Laramide positive areas in west-central New Mexico. These volcanoes shed detritus and pyroclastic material into two basins of Laramide ancestry, the Baca and Carthage–La Joya basins. Andesitic volcanism and associated sedimentation continued until about 37 Ma, and are represented today by the lower Datil Group. Bimodal volcanism supplanted andesitic volcanism in the northern Mogollon–Datil field by about 36 Ma. Basaltic andesite lavas, silicic ash-flow tuffs, and associated volcaniclastic deposits

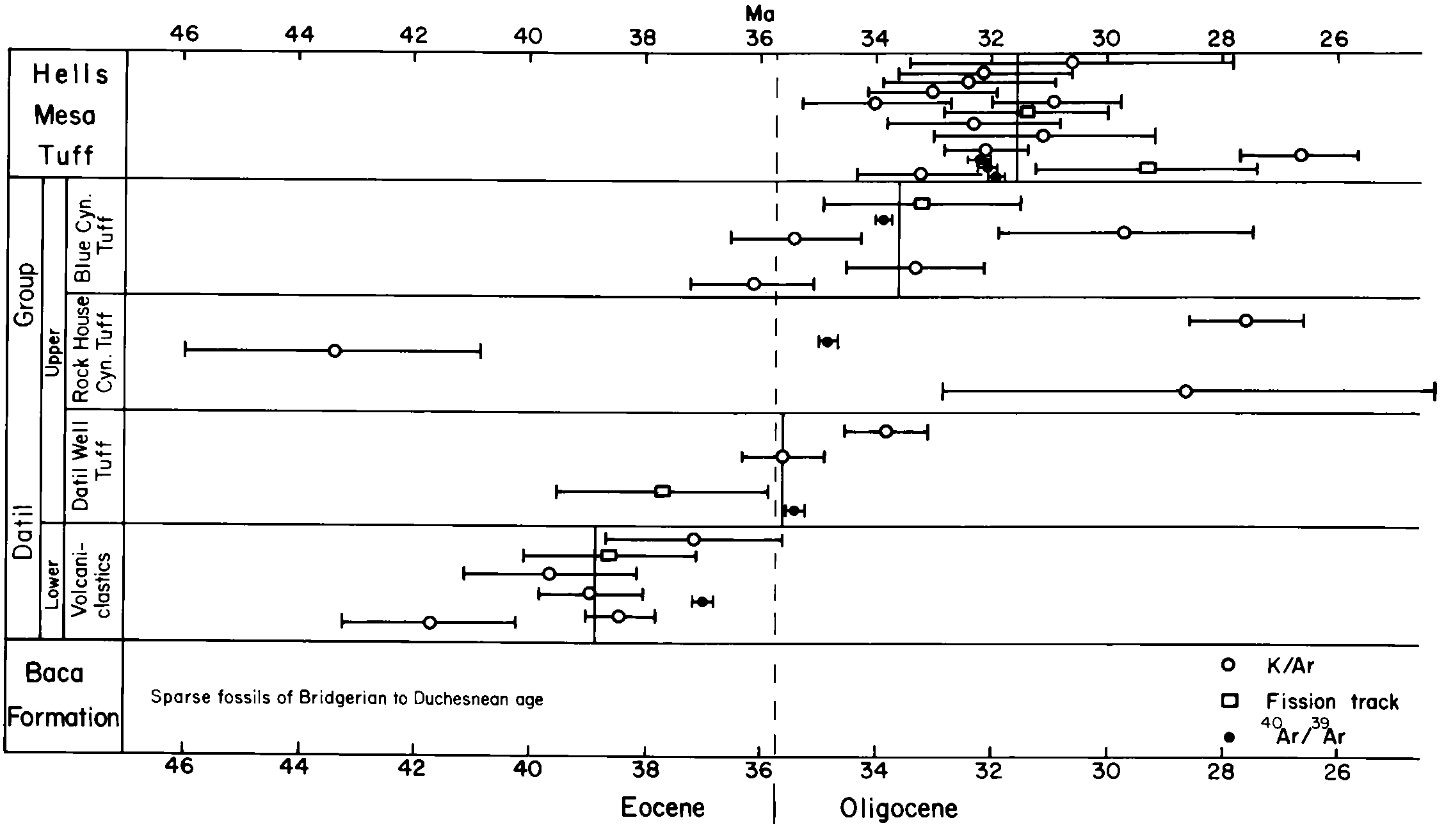

FIGURE 3—Summary of radiometric ages for Datil Group and overlying Hells Mesa Tuff. Brackets indicate one standard deviation about the mean; vertical bars indicate averages for individual units; dashed vertical line is approximate Eocene–Oligocene boundary according to Montanari et al. (1985). Sources for Datil dates are listed in Table 1. Hells Mesa Tuff dates from C. E. Chapin (unpublished), Kedzie et al. (1985), Weber (1971), Burke et al. (1963), McIntosh et al. (1986), and Marvin et al. (in press).

TABLE 1—Radiometric age determinations for the Datil Group. *Has been recently recorrelated to tuff of Taylor Well by McIntosh et al. (1986). References: **1.** Cather, 1986—dates by F. W. McDowell, University of Texas (Austin); **2.** C. E. Chapin, unpublished dates; **3.** Bornhorst et al., 1982; **4.** Burke et al., 1963 and Weber, 1971; **5.** McIntosh et al., 1986 and McIntosh, in progress. Except where noted, K/Ar ages were calculated (or recalculated) for the revised 1976 IUGS decay constants using Dalrymple's (1979) tables.

Unit	Age (Ma)	Method	Location	Reference	Remarks
lower Datil Group	38.4 ± 0.6	K/Ar (biotite)	northern Jornada del Muerto	1	Andesite conglomerate clast from about 350 m above base of section.
lower Datil Group	41.8 ± 3.0	K/Ar (plagioclase)	northern Jornada del Muerto	1	From same clast as above. This date is considered to be in error because of poor reproducibility of K and Ar analyses.
lower Datil Group	38.9 ± 0.9	K/Ar (plagioclase)	northern Jornada del Muerto	1	Andesite conglomerate clast from about 140 m above base of section.
lower Datil Group	39.6 ± 1.5	K/Ar (biotite)	western Gallinas Mountains	2	Andesite clast in debris-flow deposit. Located on southeast side of Dog Springs Canyon, about 4.8 km southwest of Martin Ranch.
lower Datil Group	38.6 ± 1.5	fission track (zircon)	Datil Mountains	3	Andesite clast from SW1/4 sec. 7, T1S, R10W.
lower Datil Group	37.1 ± 1.5	K/Ar (biotite)	Joyita Hills	4	Date calculated using old decay constants. Hornblende andesite clast from Tsp[1] unit of Spradlin (1976), near Cibola Canyon.
Datil Well Tuff*	33.8 ± 0.7	K/Ar (sanidine)	northern Jornada del Muerto	1	Tuff is about 770 m above base of section.
Datil Well Tuff	35.6 ± 0.7	K/Ar (sanidine)	Datil Mountains	3	SW1/4 sec. 2, T2S, R10W.
Datil Well Tuff	37.7 ± 1.8	fission track (zircon)	Datil Mountains	3	SW1/4 sec. 2, T2S, R10W.
Rock House Canyon Tuff	28.7 ± 4.2	K/Ar (feldspar)	northern Jornada del Muerto	1	Tuff is about 850 m above base of section. Date is geologically unreasonable, possibly due to impure mineral separate.
Rock House Canyon Tuff	43.4 ± 2.7	K/Ar (feldspar)	western Gallinas Mountains	2	Date is geologically unreasonable.
Rock House Canyon Tuff	27.6 ± 1.0	K/Ar (sanidine)	western Gallinas Mountains	3	Date is geologically unreasonable.
Blue Canyon Tuff	33.2 ± 1.7	fission track (zircon)	Crosby Mountains vicinity	3	SW1/4 sec. 1, T2S, R12W.
Blue Canyon Tuff	33.3 ± 1.2	K/Ar (biotite)	western Gallinas Mountains	2	NW1/4, SE1/4 sec. 36, T1N, R9W.
Blue Canyon Tuff	29.7 ± 2.2	K/Ar (biotite)	western Gallinas Mountains	2	SE1/4 sec. 1, T3S, R10W.
Blue Canyon Tuff	35.4 ± 1.3	K/Ar (biotite)	Joyita Hills	2	Location is about 300 m north of road to Rosa de Castillo Windmill, on east side of hogback.
Blue Canyon Tuff	36.1 ± 1.3	K/Ar (biotite)	Joyita Hills	2	Same as above.
lower Datil Group	37.02 ± 0.15	$^{40}Ar/^{39}Ar$ (hornblende)	Joyita Hills	5	Andesite clast in debris-flow deposit (Tsp–af[1] of Spradlin, 1976).
Datil Well Tuff	35.51 ± 0.15	$^{40}Ar/^{39}Ar$ (sanidine)	Datil Mountains	5	
Blue Canyon Tuff	33.93 ± 0.15	$^{40}Ar/^{39}Ar$ (sanidine)	western Gallinas Mountains	5	
Rock House Canyon Tuff	34.81 ± 0.15	$^{40}Ar/^{39}Ar$ (sanidine)	western Gallinas Mountains	5	

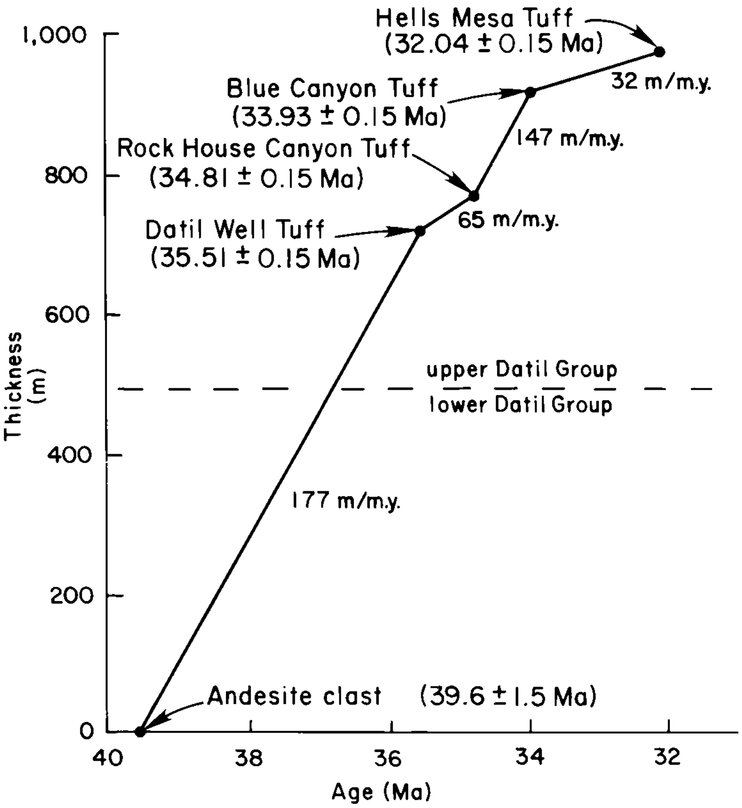

FIGURE 4—Graph showing Datil Group sedimentation rates, as determined by stratigraphic thickness and radiometric dates in the western Gallinas Mountains.

dominate the upper Datil Group (32–36 Ma) and record the late, bimodal phase of Datil volcanism. Sedimentation rates during Datil deposition in the western Gallinas Mountains area ranged from about 32 to 177 m/m.y., and appear to have diminished through time. The end of Datil Group deposition was marked by the eruption of Hells Mesa Tuff (32 Ma). Radiometric data indicate that the major petrogenetic, tectonic, and sedimentologic changes represented by the lower Datil–upper Datil contact occurred at about the Eocene–Oligocene boundary.

ACKNOWLEDGMENTS—The manuscript was improved by reviews from R. M. Chamberlin, J. W. Hawley, S. G. Lucas, and J. C. Ratté. All $^{40}Ar/^{39}Ar$ dating work was performed in cooperation with J. F. Sutter at the USGS laboratory in Reston, Virginia. F. W. McDowell of the University of Texas (Austin) contributed six new K/Ar ages. G. R. Osburn provided valuable field assistance. Financial support for this study was provided by the New Mexico Bureau of Mines and Mineral Resources (F. E. Kottlowski, Director).

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