



Latest Eocene $^{40}\text{Ar}/^{39}\text{Ar}$ Age from the Yeso Hills Dikes, Eddy County, New Mexico

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LATEST EOCENE $^{40}\text{Ar}/^{39}\text{Ar}$ AGE FROM THE YESO HILLS DIKES, EDDY COUNTY, NEW MEXICO

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ABSTRACT—The Yeso Hills dikes in southeastern New Mexico are the only surface expression of a minor set of latest Eocene–earliest Oligocene, mafic, alkaline intrusions stretching for ~150 km in the subsurface of the northern Delaware Basin. Preliminary mapping reveals a complex intrusive architecture, with each intrusion being composed of multiple dikes interconnected by sills. New high-precision $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology analysis provides a latest Eocene age of 34.45 ± 0.28 Ma for the Yeso Hills dikes. We propose that the Yeso Hills dikes are part of a coherent “Cordilleran magmatic peripheral belt” that may stretch as far north as the Canadian border in central Montana, composed of minor intrusions derived from small-volume melting beneath the western edge of the Great Plains. This distal magmatism represents farther east outliers distinct from the North American alkaline magmatic belt of the Cordilleran interior.

INTRODUCTION

The late Cretaceous to Paleogene North American alkaline magmatic belt has long been recognized as a first-order feature of the western North American Cordillera (Lindgren, 1933; McLemore, 2018). Alkaline igneous rocks and related mineral deposits form a belt that stretches from Alaska to Mexico, far inboard of the Cordilleran plate margin (Fig. 1). In the southwestern United States, Cretaceous–Paleogene alkaline igneous occurrences broadly coincide with the boundary between the Great Plains and Rocky Mountains–Rio Grande Rift provinces (McLemore, 1996; Chapin et al., 2012). Alkaline magmatism overlapped in time with voluminous, calc-alkaline magmatism to the west and the prolonged transition from Laramide contraction to Oligocene–present extension (Coney and Reynolds, 1977; Chapin et al., 2004).

Even more distal, small-volume alkaline igneous occurrences are found in the far eastward Cordillera along the western margin of the Great Plains (Fig. 2). In eastern New Mexico and southeastern Colorado, peripheral intrusions of mid-Cenozoic age are emplaced into little-deformed Permian to Cretaceous strata, some 50 to 200 km east of the nearest major alkaline magmatic centers (Luedke, 1993). These peripheral igneous occurrences may simply be far-travelled lateral offshoots (e.g., Chamberlin et al., 2009) of the alkaline magmatic centers in axial New Mexico, as has been proposed for emplacement of the Railroad Mountain and associated dikes along the eastern Capitan lineament (Fig. 2; Kelley and Thompson, 1964; Allen and Foord, 1991; McLemore and Zimmerer, 2009). Alternatively, distal intrusions may represent transcrustal magmatic systems related to small-volume melting beneath the westernmost Great Plains. In the latter case, these minor alkaline igneous occurrences would constitute a coherent “Cordilleran magmatic peripheral belt” distinct from the major magmatic centers of the North American alkaline magmatic belt to the west.

The Yeso Hills dikes, emplaced into Permian evaporite strata, are the only documented surface exposures of mid-Cenozoic intrusions that stretch over 150 km in the subsurface of

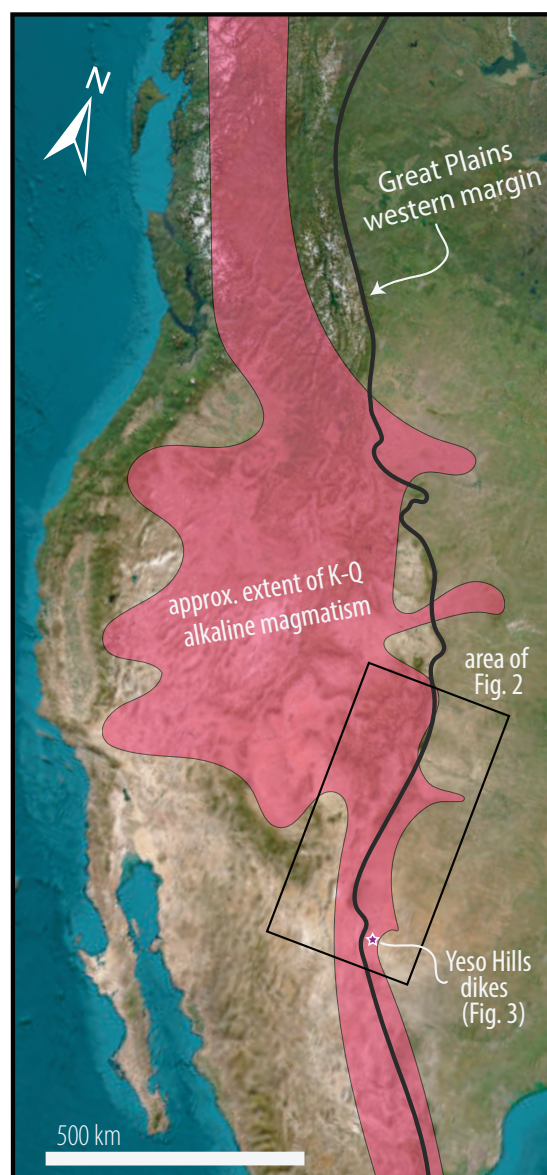


FIGURE 1. Alkaline magmatism across western North America, after McLemore (2018).

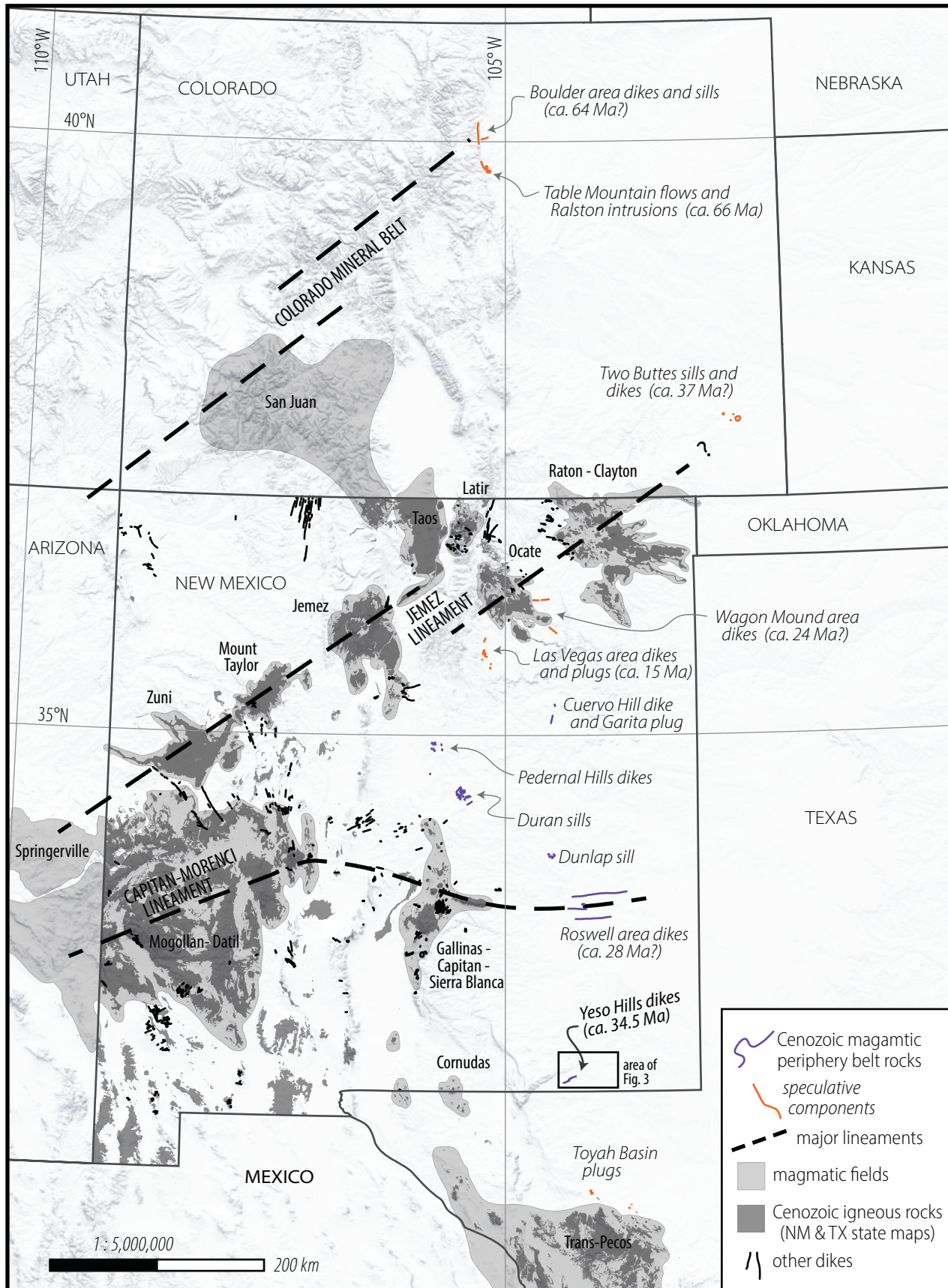


FIGURE 2. Summary of easternmost Cenozoic igneous occurrences of the proposed Cordilleran magmatic peripheral belt across New Mexico, Colorado, and Texas. Geology from Barnes (1992), NMBGM (2003), and Chapin et al. (2004). Latitude-longitude in NAD83.

the northern Delaware Basin of southeastern New Mexico and western Texas (Fig. 3; Hayes and Gale, 1957; Hayes, 1964; Kelley, 1971; Jones, 1973; Bachman, 1980). The east-north-east-trending Yeso Hills dikes were described by Pratt (1954) in the Fifth New Mexico Geological Society Fall Field Conference Guidebook. Additional intrusions have been identified in the subsurface from boreholes and underground mines, extending eastwards from the Delaware Mountains, Texas, to well east of the Pecos River (Flawn, 1952; Calzia and Hiss, 1978). Latest Eocene to early Oligocene K/Ar ages ranging from 32.2–34.8 Ma have been reported from intrusions in subsurface mines about 80 km northeast of the Yeso Hills (Calzia and Hiss, 1978; Marvin and Dobson, 1979; Brookins, 1980). Despite sparse geochemistry and geochronology, all igneous rocks of the northern Delaware Basin are interpreted to be part of one magmatic pulse (Calzia and Hiss, 1978). The nearest mid-Cenozoic alkaline magmatic center is the ca. 26–37 Ma Cornudas Mountains complex in Otero County, New Mexico, which lies about 100 km west of the Yeso Hills

(McLemore et al., 2022).

Detailed work on the Yeso Hills dikes builds on recent mapping of the Rattlesnake Springs 7.5-minute quadrangle, Eddy County (Allen and Attia, 2021), revealing that each intrusion consists of multiple dikes and sills. New $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology provides a latest Eocene emplacement age. The constituents of a speculative Cordilleran magmatic peripheral belt extending from southeastern New Mexico to northern Montana are briefly discussed below.

INTRUSIVE ARCHITECTURE

The Yeso Hills dikes are a set of subparallel intrusions that are exposed just west of U.S. Highway 180 (Fig. 4), about 5 km north of the New Mexico–Texas state line. The dikes are strongly weathered in outcrops, with negative to neutral topographic expression. The intrusions consist of greenish-gray-weathering basaltic andesite (Calzia and Hiss, 1978) emplaced into laminated gypsum and anhydrite and calcite evaporite strata of the

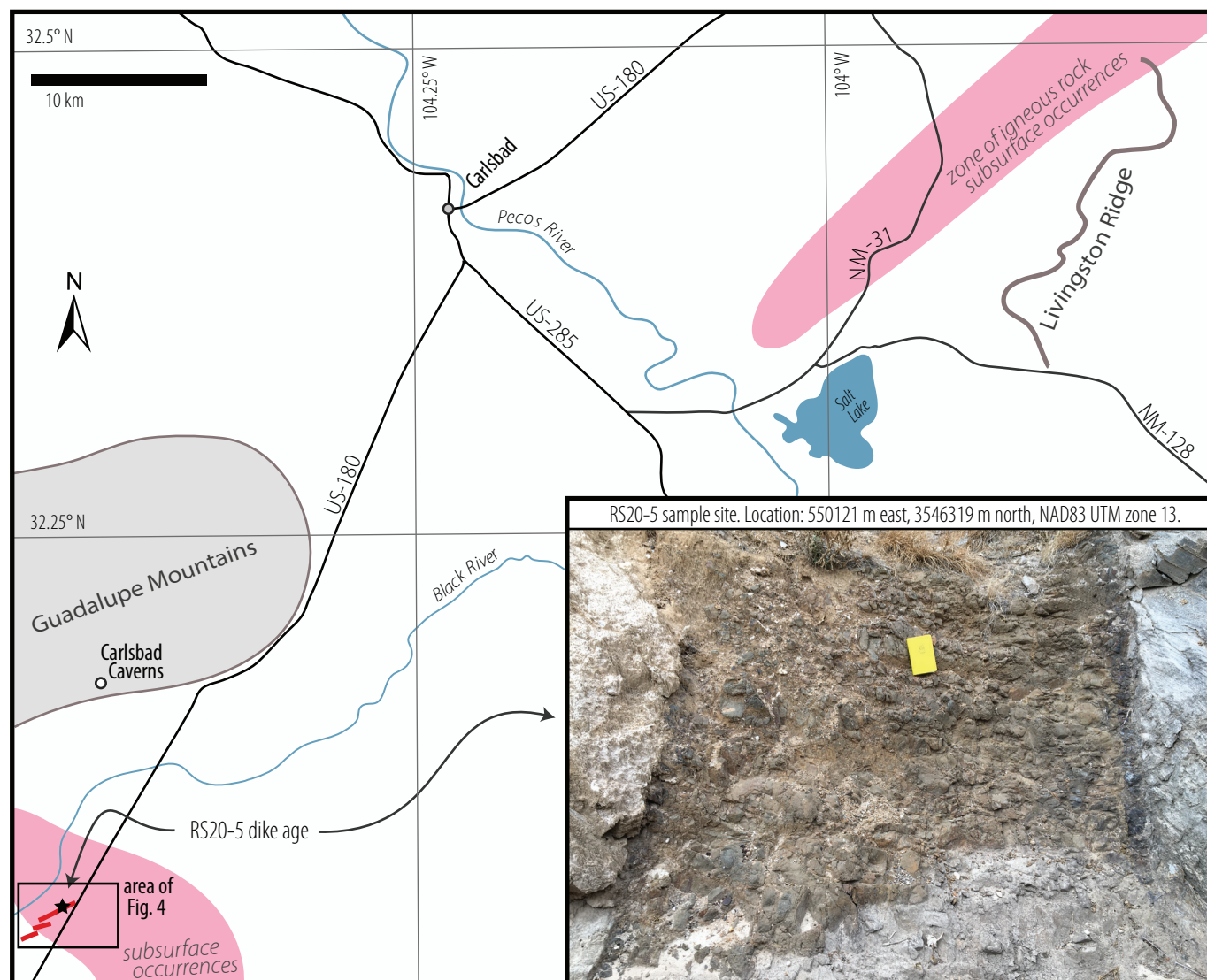


FIGURE 3. Sample location within the Lower Pecos Valley. Latitude-longitude lines in NAD83.

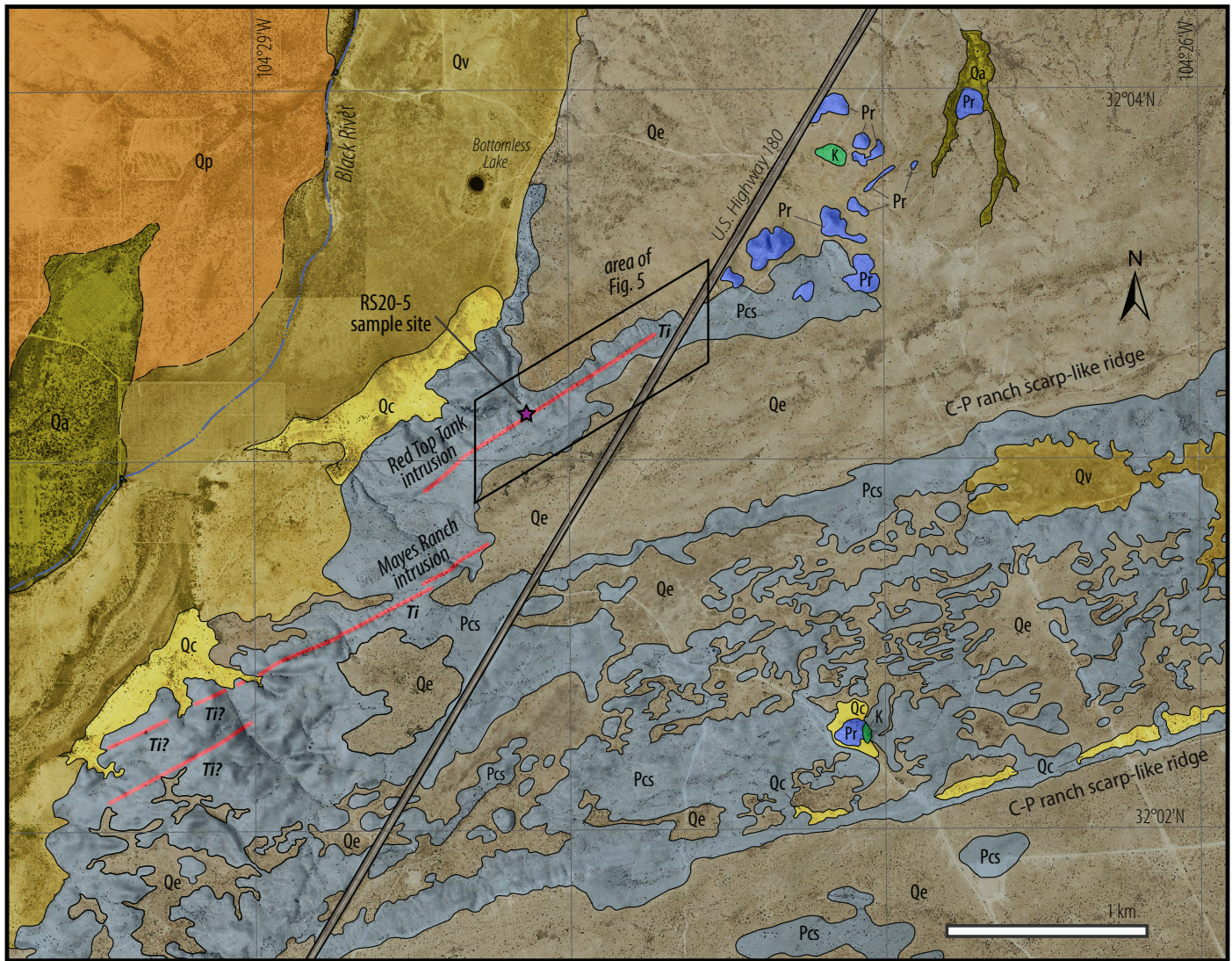


FIGURE 4. Simplified geology of the Yeso Hills dikes area from 1:24,000-scale geologic map of the Rattlesnake Springs 7.5-minute quadrangle, Eddy County (Allen and Attia, 2021). Qa – alluvial deposits, Qc – alluvium and colluvium, Qe – eolian and alluvial deposits including depression fill, Qv – alluvial, eolian, and gypsiferous valley-fill deposits, Qp – piedmont deposits, Ti – latest Eocene mafic dikes, K – Cretaceous sedimentary remnants, Pr – Rustler Formation, Pcs – undivided Salado and Castile formations. Latitude-longitude lines in NAD83.

Permian Castile Formation. Plagioclase phenocryst lathes lie in a groundmass of plagioclase, rare orthoclase, biotite, minor apatite, altered ferromagnesian minerals (pyroxene?), and magnetite, with some vesicles coated or filled with chalcedony, anhydrite, calcite, and/or chlorite (Calzia and Hiss, 1978). Preliminary mapping reveals that each of the dikes visible on aerial images actually consists of a set of dikes interconnected by sills of consistent composition and texture.

Herein, the northeasternmost dike is referred to as the “Red Top Tank intrusion” (Fig. 4) for nearby livestock tanks named on the 1945 U.S. Geological Survey Carlsbad Caverns East 15-minute quadrangle. Along the eastern portion of the Red Top Tank intrusion (Fig. 5), bedding in evaporites and minor carbonate beds generally dip 10–20°S-SE. The Red Top Tank intrusion is typically composed of three parallel to subparallel dikes, ranging in width from 0.3 to 20 m and totaling 40 m at the widest point. The entire Red Top Tank intrusion trends ~055–060. Trends of individual dikes and dike segments

show a greater range over ~045–070, clustering at ~050–055. Though sub-meter-scale contortion of primary foliation does locally appear more conspicuous near intrusive contacts, it is also present throughout the area and shows no consistent deflection approaching dike walls. The greatest spacing found between individual dikes of the Red Top Tank intrusion is ~20 m.

Where close together, individual dikes are either separated by host rock rafts or connected by sills parallel to host rock bedding (Fig. 5). The small screens of country rock are referred to as “rafts” rather than “stoped blocks,” because bedding within them is essentially subparallel to bedding in nearby strata away from the intrusion. Thus, there is no evidence for rotation of host rock blocks, and consequently space making, during emplacement (Pignotta et al., 2010). Sills with thicknesses ≤ 3 m appear to form relays between dikes and in some cases are present where individual dikes terminate (Fig. 6). Also present are host-rock “flaps” above or below sills with basal or upper

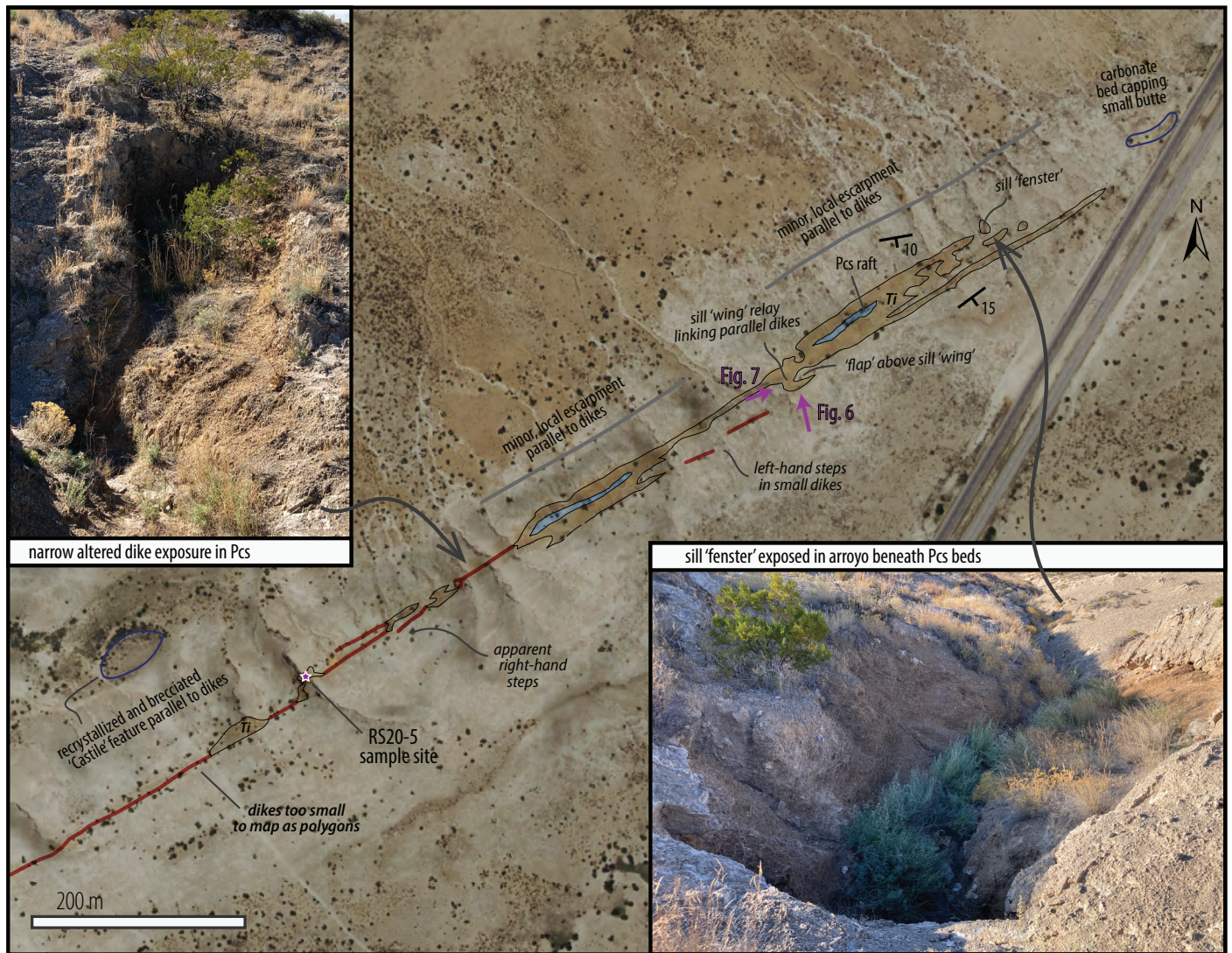


FIGURE 5. Aerial photo of the eastern part of the Red Top Tank intrusion, composed of several distinct dikes interconnected by small sills. Perspective of Figures 6 and 7 denoted by purple arrows. Ti – latest Eocene mafic intrusions, Pcs – undivided Salado and Castile formations.

contacts parallel to bedding but with bedding truncated laterally by subvertical flanking dikes (Fig. 7). Arroyos at the eastern end of the Red Top Tank intrusion expose windows through Castile Formation strata into underlying sills with contacts parallel to bedding, herein referred to as sill “fensters” (Fig. 5).

The generally subdued topography of the gypsum plain to the east of the Yeso Hills dikes is interrupted by east-northeast-trending linear valleys paralleled by steep escarpments (Fig. 4; King, 1948). These troughlike topographic features trend $\sim 075^\circ$, oblique to the Yeso Hills dikes, and are attributed to dissolution of Permian evaporites along subsurface fractures and associated subsidence (Olive, 1957; Hayes, 1964; Allen and Attia, 2021) rather than faulting (cf., Kelley, 1971, “C-P Ranch faults” on his plate 5). Similarly, differing speculations concerning the possible relationship between local bedrock structure and orientation of the Yeso Hills dikes have been offered. Kelley (1971) proposes that the intrusions were emplaced along faults, whereas Hayes and Gale (1957) invoke control by joint set orientations. Preliminary work has

not revealed shearing at dike margins, as noted by Calzia and Hiss (1978). East-west-trending, mid-Cenozoic dikes exposed east of the city of Roswell have been interpreted as distal offshoots of the Lincoln County Porphyry Belt emplaced along the Capitan lineament (McLemore and Zimmerer, 2009). No such deep-seated, regionally extensive structures parallel to the Yeso Hills dikes have been proposed to underlie the study area.

GEOCHRONOLOGY

$^{40}\text{Ar}/^{39}\text{Ar}$ analysis was performed at the New Mexico Geochronology Research Laboratory on groundmass concentrate from a sample of fine-grained dike material. Standard separation techniques were used, including crushing, cleaning with dilute HCl acid, and hand-picking of 1 mm fragments free of phenocrysts. The sample was irradiated for 21 hours in the CLOCIT position of the Triga reactor (Oregon State University, USA), with the 28.201 Ma FC-2 sanidine standard as the flux monitor (cf., Kuiper et al., 2008). Calcium and potassium

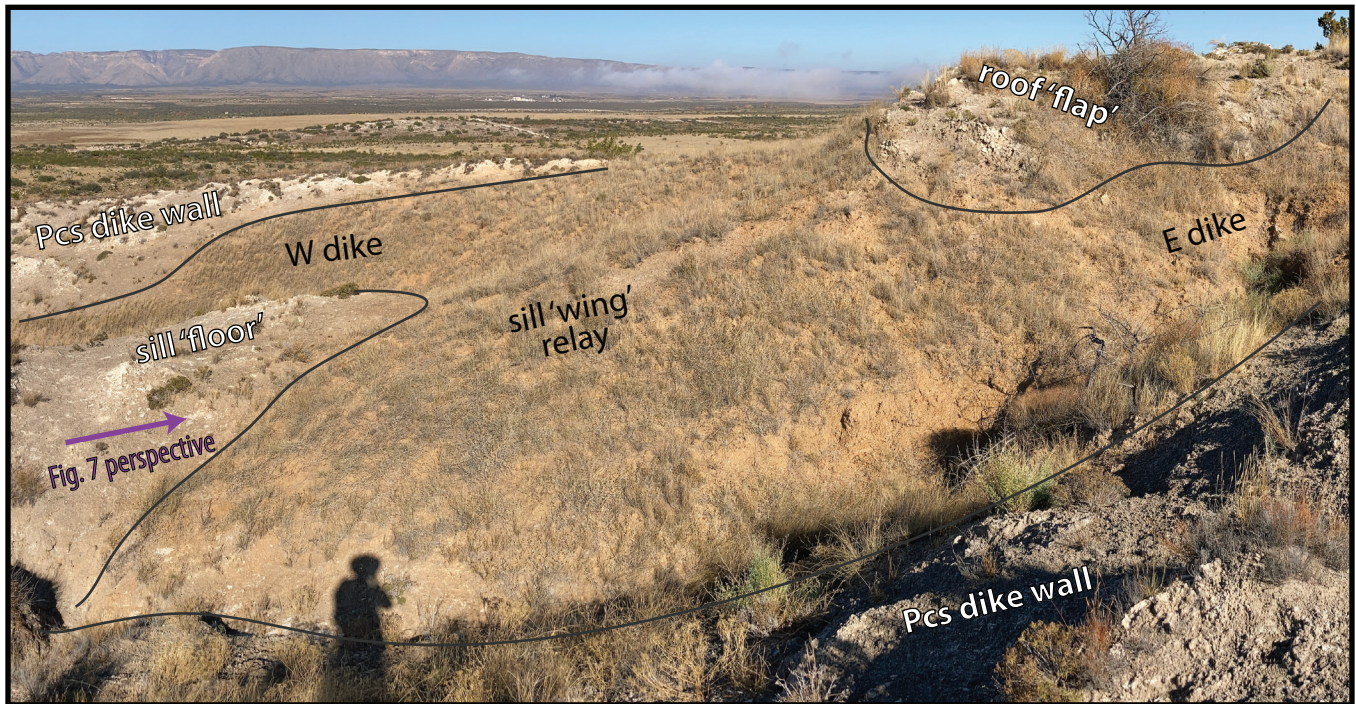


FIGURE 6. Field photo looking north, across-strike of the dikes, at a sill that connects two parallel dikes, with the Black River Valley and Guadalupe Ridge in the background. The roof and floor contacts of the sill are exactly parallel to bedding over the ~10 m strike of the sill.

correction factors were determined by irradiation of CaF_2 and K-Glass. Atmospheric ^{40}Ar was estimated using an initial $^{40}\text{Ar}/^{36}\text{Ar}$ ratio of 295.5 ± 0.5 (Nier, 1950). The total ^{40}K decay constant of Min et al. (2000) is used. The sample was analyzed by the step-heating method, using a defocused diode laser. Argon isotopes were measured using a Thermo-Fisher Scientific Helix MC-plus multi-collector mass spectrometer. All ages are reported with 2-sigma uncertainties.

Sample RS20-5 (NAD83 zone 13 UTM coordinates: 550121 E/3546319 N) was collected from a relatively fresh exposure of the Red Top Tank intrusion in a deeply scoured arroyo just west of U.S. Highway 180 (Figs. 3, 4, 5). Geochronology analysis yields an overall complex age spectrum with discordance in the initial heating steps followed by a slight saddle shape (Fig. 5). The initial climbing age steps from 25 to 35 Ma over the first 20% of ^{39}Ar released, probably due to partial argon loss during weathering and/or alteration. The discordance of the spectrum does not allow determination of a statistically rigorous plateau age. Nevertheless, the relatively flat segment observed for the final 60% of ^{39}Ar released provides a weighted mean age of 34.45 ± 0.28 Ma, interpreted as the dike crystallization age (Fig. 8; Table 1). This age is consistent with the 32.2–34.8 Ma K-Ar ages previously reported from subsurface dikes northeast of the Yeso Hills (Calzia and Hiss, 1978; Marvin and Dobson, 1979; Brookins, 1980), supporting a single pulse of short-lived magmatism in the northern Delaware Basin.

CORDILLERAN MAGMATIC PERIPHERY

The Yeso Hills dikes are part of a patchy band of minor intrusions emplaced into relatively little-deformed strata at the

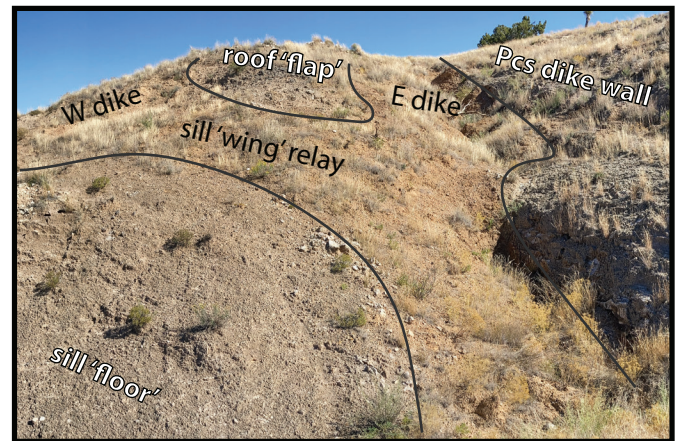


FIGURE 7. Field photo looking east-northeast, along-strike of the dikes, at the same sill "relay" and parallel dikes as Figure 6.

western edge of the Great Plains, forming the most distal loci of Cordilleran magmatism. Other elements of this belt shown in Figure 2 include the Railroad Mountain and Camino del Diablo dikes and associated intrusions of mid-Oligocene age near Roswell and the Dunlap sill farther north (Semmes, 1920; Dane and Bachman, 1958; Kelley, 1971; Kress et al., 1985); the Duran sills, Culebra dike, and northern Pedernal Hills dikes in Torrance County, NM (Kelley, 1972); a dike near Cuervo Hill in Guadalupe County, NM (Bartsch-Winkler, 1992); and a small plug near Garita Creek in southern San Miguel County, NM (Griggs and Henderson, 1951). The Cuervo Hill dike and Garita Creek plug are broadly coincident with subsurface syenite or episyenite of uncertain age reported from boreholes (Broadhead and King, 1988).

TABLE 1. ⁴⁰Ar/³⁹Ar geochronology analytical data.

ID	Power	⁴⁰ Ar/ ³⁹ Ar	³⁷ Ar/ ³⁹ Ar	³⁶ Ar/ ³⁹ Ar	³⁹ Ar _K	K/	⁴⁰ Ar*	³⁹ Ar	Age	⁴⁰ Ar	³⁹ Ar	³⁸ Ar	³⁷ Ar	³⁶ Ar	±1σ
(Watts)					(x10 ⁻¹⁵ mol)	Ca	(%)	(%)	(Ma)	±1σ	±1σ	±1σ	±1σ	±1σ	±1σ
RS20-5, Groundmass, 10.1 mg, J=0.0026876±0.06%															
x A	0.8	61.11	1.06	0.19	8.94	0.48	8.33	2.60	24.89	0.72	546.1922	0.0682	8.8140	0.0087	0.0058
x B	1.3	24.42	1.40	0.06	23.35	0.37	27.73	9.40	33.03	0.24	570.2088	0.0640	22.9733	0.0090	0.0051
x C	1.6	16.99	0.73	0.03	35.71	0.70	42.29	19.79	35.84	0.14	606.8097	0.0690	35.1103	0.0101	0.0052
x D	1.9	13.95	0.55	0.02	38.48	0.93	51.65	30.99	35.10	0.11	536.7755	0.0624	37.8410	0.0100	0.0055
E	2.2	14.04	0.59	0.02	36.23	0.86	50.42	41.54	34.50	0.11	508.6447	0.0717	35.6111	0.0100	0.0055
F	3.0	14.61	0.67	0.03	68.51	0.76	47.76	61.48	34.02	0.10	1001.1292	0.0885	67.3432	0.0112	0.0053
G	5.0	13.28	0.91	0.02	75.56	0.56	53.15	83.47	34.41	0.08	1017.1152	0.0851	75.2681	0.0117	0.0056
H	7.0	13.57	0.82	0.02	25.27	0.63	52.68	90.83	34.84	0.14	342.9006	0.0552	24.8409	0.0091	0.0056
I	10.0	12.27	0.84	0.02	20.55	0.61	58.25	96.81	34.84	0.15	252.2288	0.0467	20.2064	0.0098	0.0057
J	15.0	11.38	0.89	0.01	10.96	0.57	63.37	100.00	35.15	0.24	124.7209	0.0375	10.7884	0.0088	0.0054
Integrated age ± 1s		n=10		343.6		34.31		0.04							
Steps E-J ± 1s		n=6		237.1		69.01		34.45		0.14 MSWD=9.1					

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.

Errors quoted for individual analyses include analytical error only, without interfering reaction or J uncertainties.

Integrated age calculated by summing isotopic measurements of all steps.

Integrated age error calculated by quadratically combining errors of isotopic measurements of all steps.

Plateau age is inverse-variance-weighted mean of selected steps.

Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.

Plateau error is weighted error of Taylor (1982).

Isotopic abundances after Steiger and Jäger (1977).

X preceding sample ID denotes analyses excluded from plateau age calculations.

Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.201 Ma (Kuiper et al., 2008).

Decay Constant (LambdaK (total)) = 5.463e-10/a (Min et al., 2000).

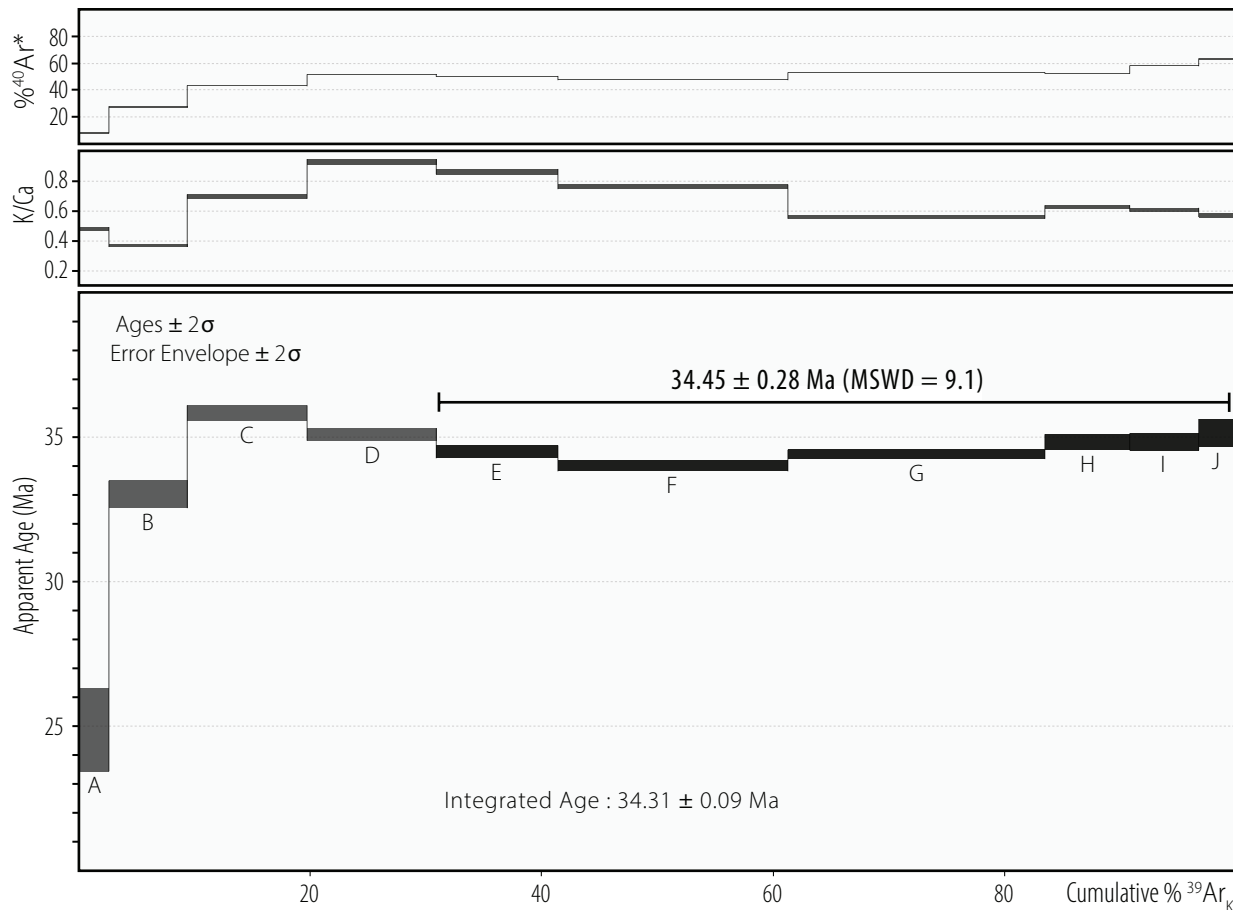


FIGURE 8. New $^{40}\text{Ar}/^{39}\text{Ar}$ groundmass age analysis results from sample RS20-5. Bottom panel shows $^{40}\text{Ar}/^{39}\text{Ar}$ apparent age spectrum, Ca/K in the middle, and percentage of radiogenic ^{40}Ar spectra in top panel. Data reduction and interpretation using PyChron (Ross, 2014).

The Cordilleran magmatic periphery may stretch into west Texas (Parker and McDowell, 1979) and also farther north in New Mexico, including mid-Miocene plugs and dikes near Las Vegas, NM (Ogilvie, 1902; Lisenbee, 2003; Skotnicki, 2003; Petronis et al., 2015) and a small set of latest Oligocene dikes near Wagon Mound, NM (Wanek, 1962; Kress et al., 1985; Scott, 1986). These northern intrusions could alternatively be considered mid-Cenozoic precursors to late Miocene and younger magmatism along the eastern Jemez lineament (e.g., Chapin et al., 2004; Zimmerer et al., 2019). Late Eocene intrusions at Two Buttes in southeastern Colorado (Davis et al., 1996), the easternmost expression of Cenozoic magmatism in western North America, may represent the northernmost extension of distal mid-Cenozoic intrusions.

Farther north in Colorado, the most peripheral igneous rocks are Cretaceous to Paleogene in age (ca. 66 Ma), broadly coeval with Laramide orogenic activity, and emplaced into tilted strata. These include the Table Mountain flows, Ralston intrusions, Valmont Butte dike, Flagstaff Mountain sill, and coeval intrusions near Golden, Boulder, and Lyons, CO (Hoblitt and Larson, 1975; Drewes, 2008; Millikin et al., 2018). Mid-Cenozoic intrusions are found in similar geologic context at the westernmost Great Plains in the Sweet Grass Hills of northernmost central Montana (Marvin et al., 1980). Mid-Cretaceous kim-

berlites are also known farther east of the Rocky Mountains in Arkansas, Kansas, and Saskatchewan, but these features are not conclusively linked to the western North American Cordillera (e.g., Currie and Beaumont, 2011).

We speculate that these distal igneous occurrences form a coherent “Cordilleran magmatic peripheral belt” representing transcrustal magmatic systems driven by small-volume melting beneath the westernmost Great Plains. Further work is needed to better understand the age, composition, petrogenesis, and tectonic significance of these easternmost igneous rocks that would comprise this speculative belt. Applying a whole-system approach that synthesizes all new and existing map, field, and analytical data (e.g., Chapman et al., 2021) to these distal intrusions, as well as the wider North American alkaline magmatic belt, will likely lead to significant new insights. Such work may also provide constraints on lithospheric evolution, exhumation, and landscape development of the westernmost Great Plains through petrology and thermochronology analyses (e.g., Abbott et al., 2022). These topics are especially relevant given recent challenges highlighting that the spatiotemporal patterns of deformation and magmatism across the Cordillera are under-constrained and potentially inconsistent with prevailing paleotectonic models (e.g., Glazner, 2022; Busby et al., 2023).

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