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Dr. Theodore J. Taylor
Salt Repository Project Office
U. S. Department of Energy
110 North 25 Mile Avenue
Hereford, TX 79045

Reference: Contract No. DE-AC97-83WM46651

Dear Dr. Taylor:

Per a request from Susan Heston to Chris Lewis, the status of the open-file report entitled "Basin and Range-Age Reactiviation of Rocky Mountain Structures in the Texas Panhandle, (OF-WTWI-1986-3)," by R. Budnik, is as follows. Dr. Budnik left the Bureau in August, 1986. The manuscript was revised by Dr. Budnik to reflect comments from GSA reviewers and resubmitted to the journal before DOE comments were received at the Bureau. The article was published in the February, 1987 issue of Geology.

Please note the title of the article was changed, it is now entitled "Late Miocene Reactivation of Ancestral Rocky Mountain Structures in the Texas Panhandle: A Response to Basin and Range Extension." Three copies of the reprinted article are enclosed. Also, the above referenced article supersedes OF-WTWI-1986-3. If you have any questions, please do not hesitate to contact me.

Sincerely,

Doug Ratcliff/lam
Doug Ratcliff
Associate Director

DCR:CL:cl
Enclosures

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F. Brown
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S. Doenges
L. Drover (BPMD/TIC)
J. Ellenberger (SRPO)
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R. Helgerson (BMI/ONWI)
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E. Washer (S&W)
J. Williams (SRPO)
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Late Miocene reactivation of Ancestral Rocky Mountain structures in the Texas Panhandle: A response to Basin and Range extension

Roy T. Budnik*
Bureau of Economic Geology, University of Texas
University Station Box X, Austin, Texas 78713

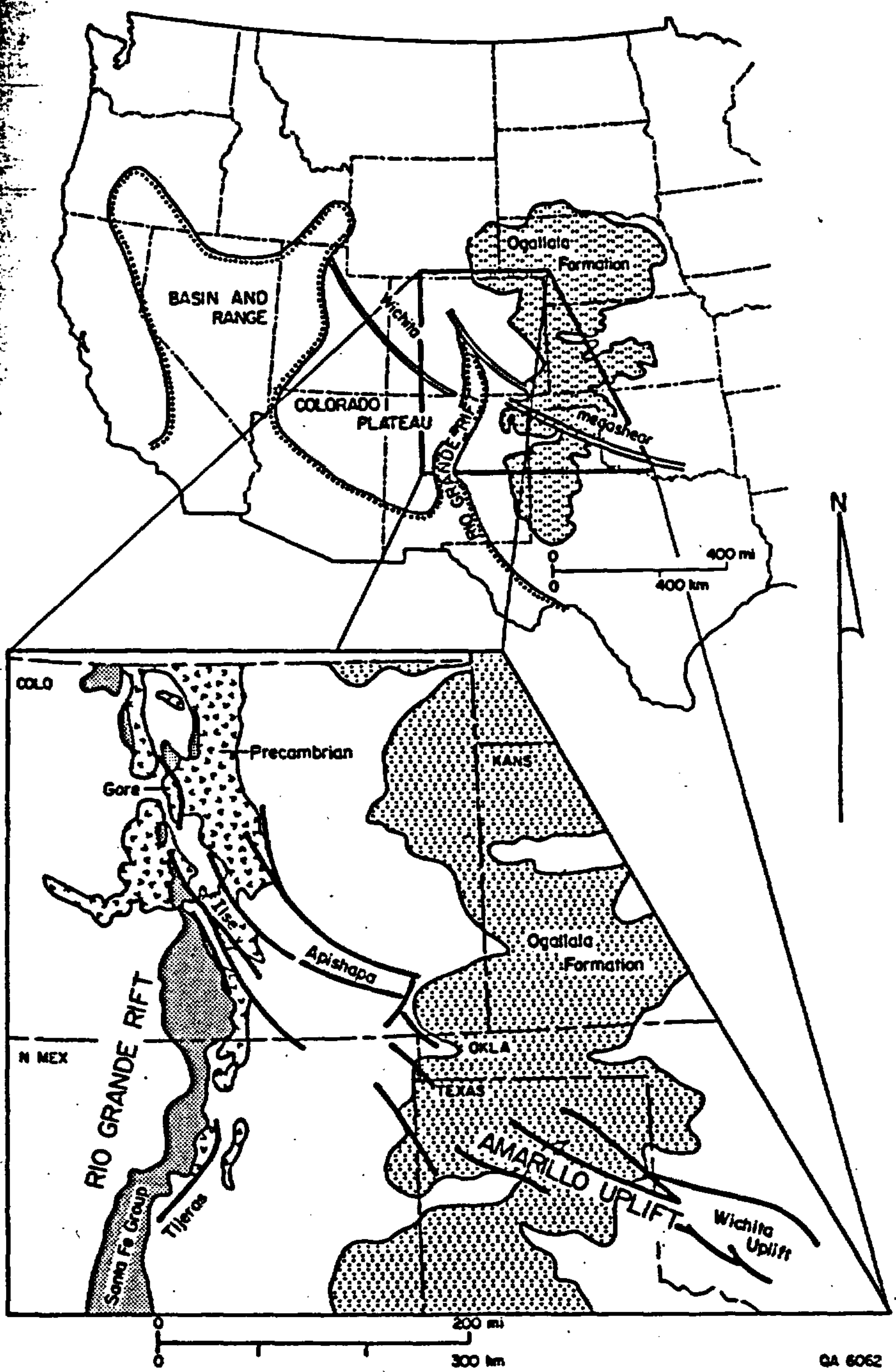

Figure 1. Basin and Range province of western United States (top) and distribution of Neogene sediments in southern Rocky Mountains and western Great Plains (bottom). Heavy lines in bottom figure are pre-Cenozoic faults.

ABSTRACT

Structural and stratigraphic evidence from the Ogallala Formation (Neogene) documents late Miocene tectonic activity within the Great Plains. Field and subsurface studies in the Texas Panhandle indicate that parts of the Amarillo uplift, a major element of the Pennsylvanian Ancestral Rocky Mountains, were elevated as much as 150 m during initial deposition of the Ogallala Formation. Reactivation of these basement structures occurred in response to Basin and Range extension and opening of the Rio Grande rift in central New Mexico and Colorado.

INTRODUCTION

Investigations in the Texas Panhandle document late Tertiary tectonism within the Great Plains, more than 300 km beyond the known limits of contemporary Basin and Range faulting in central New Mexico. Evidence of tectonic activity within the panhandle comes primarily from the Ogallala Formation, a vast alluvial apron that was shed eastward from mountains bordering the Rio Grande rift in central New Mexico and Colorado during Neogene time (Fig. 1). Previous work in the panhandle suggested that distribution of the Ogallala was controlled primarily by preexisting topography and by subsidence related to the dissolution of underlying evaporites (Seni, 1980; Gustavson and Budnik, 1985). However, recent neotectonic studies, part of a larger program examining the feasibility of siting a high-level nuclear waste repository in the Texas Panhandle, has shown that, at least locally, tectonic processes also affected the distribution and structural attitude of the Ogallala Formation. This paper reports on research conducted along the Amarillo uplift in the central panhandle about 75 km northeast of the proposed repository site.

*Present address: RR1, Box 440, Amenia, New York 12501.

STRUCTURAL GEOLOGY OF THE AMARILLO UPLIFT

The Amarillo uplift is a narrow basement positive element that is part of a complex zone of horsts and grabens extending west-northwestward across the Texas Panhandle (Fig. 2). The Amarillo uplift and colinear Wichita uplift to the southeast in Oklahoma form the southern margin of the Anadarko basin and are part of the Pennsylvanian Ancestral Rocky Mountain orogenic belt that extends from Oklahoma to Utah (ver Wiebe, 1930). Left-lateral motion of as much as 120 km during the Pennsylvanian is indicated by the offset of lower Paleozoic strata across the uplift (Budnik, 1986).

Several thousand metres of structural relief developed between the Amarillo uplift and adjacent basins to the northeast (Anadarko) and southwest (Whittenburg trough; Fig. 2) during the Pennsylvanian and Early Permian. Reactivation of Pennsylvanian structures since the Paleozoic is indicated by faulting of the Triassic Dockum Group against Permian strata across the Potter County fault, which separates the Whittenburg trough from the Amarillo uplift. In addition, middle and Upper Permian and Triassic strata have been folded over en echelon basement horsts (for example, the Exell and John Ray domes; Fig. 2) along the upthrown side of the fault. The Ogallala Formation also has been folded; this suggests that at least some of the deformation occurred in the Cenozoic.

LATE TERTIARY SYNTECTONIC DEPOSITION IN THE TEXAS PANHANDLE

Along the Amarillo uplift, basal Ogallala sands and gravels (called the Potter Formation; Patton, 1923) include well-rounded siliceous clasts as large as 30 cm in diameter transported from mountains along the eastern margin of the Rio Grande rift (Schultz, 1977), as well as blocks of dolomite and red mudstone up to 45 cm in diameter derived from underlying Permian strata. The Potter Formation is more than 100 m thick within the Whittenburg trough, but thins abruptly onto the Amarillo uplift across the Potter County fault (Fig. 3). The unit is conformably overlain within the trough by finely laminated calcareous siltstone and mudstone (Coetas Formation; Patton, 1923). Undifferentiated upper Ogallala sand, silt, and caliche blanket the entire area, including the folds adjacent to the Potter County fault.

Vertebrate fossil data from the Texas Panhandle indicate onset of deposition of the Ogallala Formation during the Clarendonian (late Miocene), about 10 Ma (Schultz, 1977; Winkler, 1985). The Potter Formation apparently has no indigenous fauna preserved, but worn Gryphaea (Early Cretaceous) fragments are common in it and other basal Ogallala (Clarendonian) deposits throughout the southern High Plains (Schultz, 1977). The overlying Coetas Formation contains a Clarendonian vertebrate fauna (Schultz, 1977). Paleontologic and isotopic data indicate that Ogallala deposition ended during the Hemphillian Stage (late Miocene/early Pliocene) 4 to 5 Ma (Izett, 1975). The upper part of the Ogallala Formation is undated in the vicinity of the uplift, but it is lithologically similar to and in the same stratigraphic position as the Bridwell Formation (Evans, 1949) to the south, which is Hemphillian in age (Winkler, 1985). Isotopic ages ranging from 4.5 to 6.6 Ma were obtained from ash beds near the top of the Ogallala Formation in Hemphill County, just north of the uplift (Izett, 1975). The Ogallala is locally overlain by Blancan (Pliocene) lacustrine deposits (Schultz, 1977) to the south of the uplift.

LATE TERTIARY DEFORMATION IN THE TEXAS PANHANDLE

Structures along the Amarillo uplift appear to have been unaffected by the Laramide orogeny to the west, as indicated by parallelism of bedding in the lower part of the Ogallala Formation and underlying units. However, Permian, Triassic, and lower Ogallala strata dip as much as 15° off the southwest flank of the John Ray dome, documenting reactivation of the older structures after initiation of Ogallala deposition. An angular unconformity lies between the Tertiary and older units higher on the dome, and the Ogallala

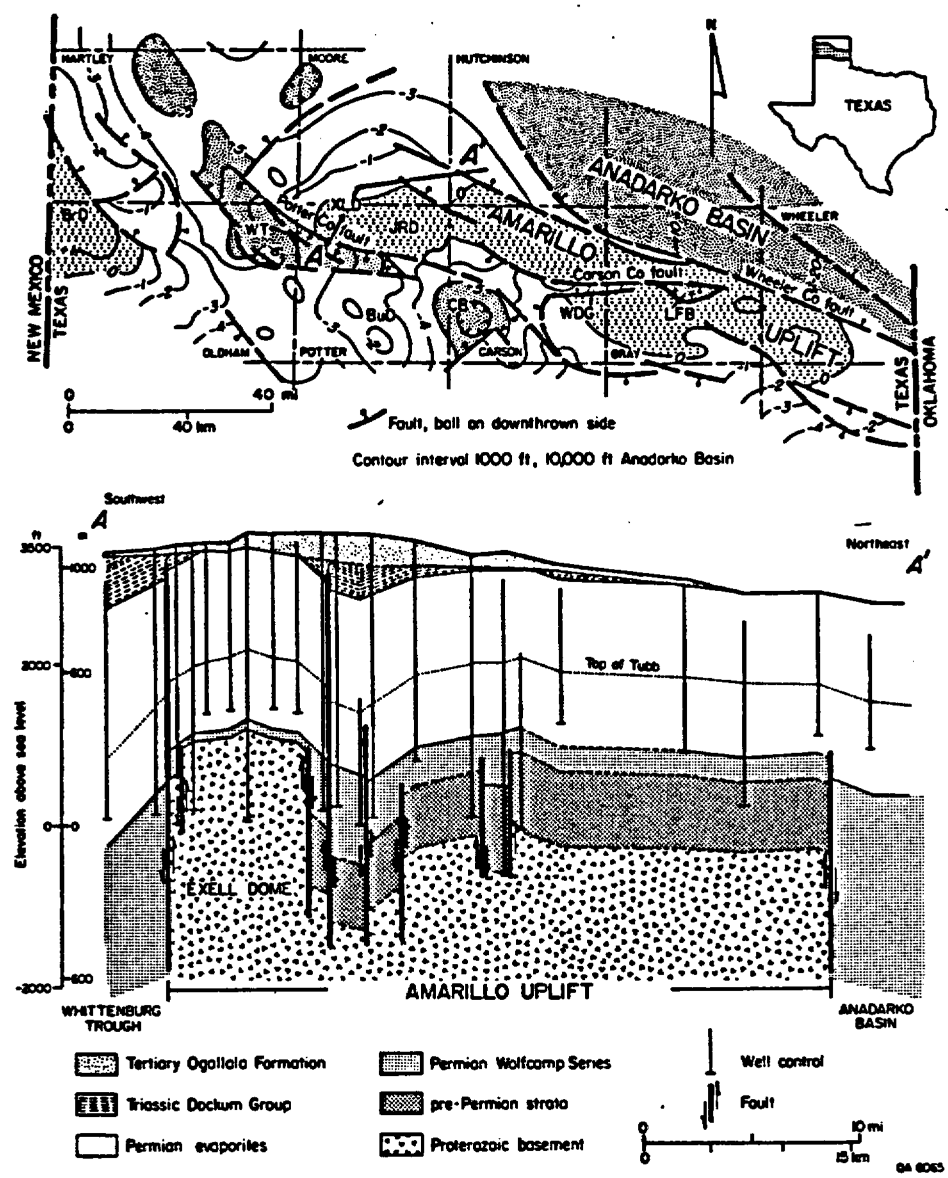

Figure 2. Structure contour map on top of basement (top) and cross section of Amarillo uplift (bottom). BrD = Bravo dome; BuD = Bush dome; CB = Carson basin; JRD = John Ray dome; LFB = Lefors basin; WDG = White Deer graben; WT = Whittenburg trough; XLD = Exell dome. Uplift of Exell dome occurred prior to deposition of upper part of Ogallala Formation. Evidence to east (see Fig. 3) suggests that deformation took place during deposition of lower Ogallala units (Potter and Coetas Formations), which are not present along this line of section.

lies successively on the Dockum Group, on Permian strata, and finally on eroded Permian strata on the apex of the structure (Fig. 3). In addition, the Ogallala appears to lap onto the dome so that the Potter Formation rests on the Dockum Group within the Whittenburg trough, whereas the upper unit of the Ogallala rests directly on Permian strata on the apex of the John Ray dome (Fig. 3). Dips decrease upward within the section, and the upper part of the Ogallala is merely gently draped over the dome (Fig. 3). Abrupt thinning across basement faults and incorporation of large Permian dolomite and mudstone fragments within the Potter Formation suggest growth of faults and unroofing of the folds during deposition.

LATE TERTIARY DEFORMATION IN THE SOUTHERN ROCKY MOUNTAINS

Deposition and deformation of the Ogallala Formation along the Amarillo uplift coincided with Basin and Range extension and opening of the Rio Grande rift in central New Mexico and Colorado (Schultz, 1977; Chapin, 1979; Cordell, 1982; Baldridge et al., 1984). Three phases of deformation have been recognized along the rift (Chapin and Seager, 1975; Golombek et al., 1983): (1) formation of broad basins from about 30 Ma until 10 or 12 Ma under west-southwest–east-northeast extension (Zoback et al., 1981; Morgan and Golombek, 1984); (2) acceleration of rifting and development of narrow fault-bounded basins and marginal uplifts beginning about 10 to 12 Ma, coincident with a change to west-northwest–oriented extension (Zoback et al., 1981); and (3) reduced fault activity and development of throughgoing axial drainage from about 4 to 5 Ma to the present.

Extension across the Rio Grande rift was accommodated in part by reactivation of preexisting fault zones (Eaton, 1979; Tweto, 1979; Cordell, 1982; Baldridge et al., 1984). Faults associated with the north-northwest–trending Ilse-Gore fault system (Tweto, 1980) influenced the location of small, discontinuous rift basins in central and northern Colorado (Fig. 1; Taylor, 1975; Chapin, 1979; Tweto, 1979). The Tijeras and other north- to northeast-trending faults in northern and central New Mexico border relatively wider, deeper, and more continuous axial basins (Miller et al., 1963; Chapin and Seager, 1975; Kelley, 1979; Tweto, 1979; Cordell, 1982). Basins along the entire rift were filled with fluvial, eolian, and lacustrine material (the Santa Fe Group and related units) derived from bordering uplifts primarily during the late Miocene to early Pliocene (Clarendonian and Hemphillian stages; Galusha and Blick, 1971; Tedford, 1981). The decrease in fault activity at about 4 to 5 Ma is indicated by the presence of relatively undeformed basalt flows and Blancan (Pliocene) ancestral Rio Grande fluvial deposits that unconformably overlie faulted, strongly tilted, and eroded strata of the Santa Fe Group (Chapin and Seager, 1975; Seager et al., 1984).

MODEL OF LATE TERTIARY DEFORMATION

Coincidence in timing of late Tertiary deformation in the southern Rocky Mountains and the southern Great Plains suggests a tectonic connection between the two areas. This is consistent with an older, throughgoing zone of weakness between Colorado and Texas that was proposed many years ago (ver Wiebe, 1930) and termed variously the Wichita lineament (Sales, 1968), the Wichita megashear (Walper, 1970; Budnik, 1986), the Olympic-Wichita lineament (Baars, 1976), and the Oklahoma–New Mexico–Colorado–Utah tectonic zone (Larson et al., 1985). The Ilse-Gore and Apishapa fault systems and Amarillo and Wichita uplifts, elements of the Ancestral Rocky Mountains, constitute the central and eastern parts of the megashear (Budnik, 1986). Evidence of late Tertiary tectonic activity along the Amarillo uplift and Ilse-Gore fault system suggests that the Wichita megashear was reactivated during the Cenozoic.

The presence of this preexisting zone of weakness appears to have influenced the pattern of Basin and Range extension in the southern Rocky Mountains. The Rio Grande rift is a relatively wide and continuous feature in New Mexico, but it becomes narrower and less continuous at its intersection with the megashear to the north. This northward narrowing has been attributed to clockwise rotation of the Colorado Plateau about an Euler pole in central or northern Colorado (Cordell, 1982). However, the discovery of contemporaneous faulting in the Texas Panhandle necessitates a modification of this model to account for deformation to the east of the rift. The model herein proposed includes both clockwise rotation of the Colorado Plateau with respect to the midcontinent, with possible right slip on the Ilse-Gore fault system, and also counterclockwise rotation of eastern New Mexico and Texas, with possible left slip on the Potter County fault (Fig. 4). Late Tertiary wrench

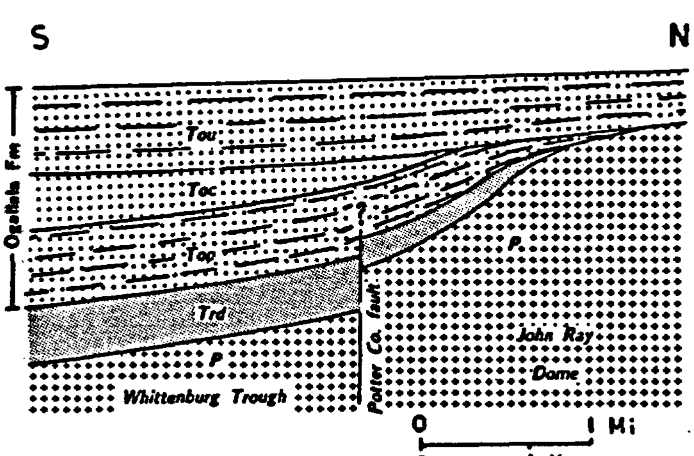

Figure 3. Diagrammatic cross section from Whittenburg trough to John Ray dome, Texas Panhandle. Neogene Ogallala Formation consists of three units: Tou = undifferentiated upper unit; Toc = Coetas Formation; Top = Potter Formation. Trd = Dockum Group; P = Permian strata. Dashed lines within Tou and Top schematically indicate bedding. No vertical scale.

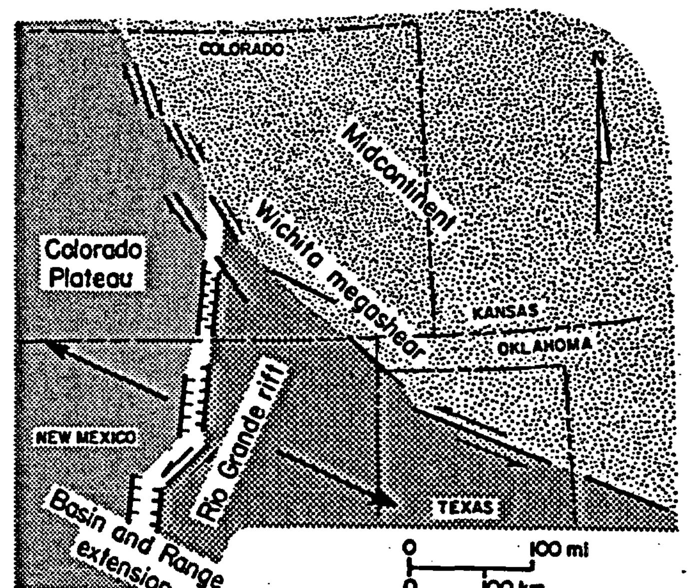

Figure 4. Neogene tectonic setting of southern Rocky Mountains and Great Plains. Large arrows indicate direction of extension 10 Ma to present. Small arrows indicate proposed direction of movement on faults. Wichita megashear formed boundary between stable midcontinent and region influenced by Basin and Range extension.

faulting has not been reported from Colorado, although the small, discontinuous rift basins in this area are reminiscent of pull-apart grabens found elsewhere along strike-slip fault zones (Reading, 1980). Likewise, no evidence of Miocene wrench faulting has been discovered in the Texas Panhandle, but the reactivation of en echelon basement horsts along the Potter County fault is at least consistent with such an interpretation. Thus, the eastern segment of the megashear may have, in essence, formed an intracratonic transform fault, separating the area undergoing Basin and Range extension on the south from the stable midcontinent to the north (Fig. 4).

IMPLICATIONS

The Wichita megashear is a long-lived feature, the documented tectonic activity occurring in the Cambrian (Larson et al., 1985), Pennsylvanian (Budnik, 1986), and late Tertiary (this paper). Although recent activity has been recognized along faults associated with the megashear in southwestern Oklahoma (the Meers fault; Donovan et al., 1983), the Texas Panhandle (Budnik and Davis, 1985), and Colorado (Kirkham and Rodgers, 1981), the potential for further activity in the region has not been fully evaluated. Major zones of crustal weakness may have a significant impact on the tectonic stability of an otherwise relatively stable region. These zones must be examined particularly closely when assessing the neotectonics of a region for the purposes of siting a sensitive facility such as a nuclear-waste repository.

REFERENCES CITED

Baars, D.L., 1976, The Colorado Plateau aulacogen—Key to continental scale basement rifting: Proceedings, International Conference on Basement Tectonics, 2nd: Denver, Colorado, Basement Tectonics Committee, Inc., p. 157–164.

Baldridge, W.S., Olsen, K.H., and Callender, J.F., 1984, Rio Grande rift: Problems and perspectives, *in* Baldridge, W.S., et al., eds., Rio Grande rift: Northern New Mexico: Socorro, New Mexico, New Mexico Geological Society, 35th Field Conference Guidebook, p. 1–12.

Budnik, R.T., 1986, Left-lateral intraplate deformation along the Ancestral Rocky Mountains: Implications for late Paleozoic plate motions: Tectonophysics.

Budnik, R.T., and Davis, S.D., 1985, Tectonic history of the Amarillo-Wichita uplift and its bearing on recent deformation along the Meers fault: Seismological Society of America Earthquake Notes, v. 55, p. 7.

Chapin, C.E., 1979, Evolution of the Rio Grande rift—A summary, *in* Riecker, R.E., ed., Rio Grande rift: Tectonics and magmatism: Washington, D.C., American Geophysical Union, p. 1–5.

Chapin, C.E., and Seager, W.R., 1975, Evolution of the Rio Grande rift in the Socorro and Las Cruces areas, *in* Seager, W.R., et al., eds., Las Cruces country: Socorro, New Mexico, New Mexico Geological Society, 26th Field Conference Guidebook, p. 297–321.

Cordell, L., 1982, Extension in the Rio Grande rift: Journal of Geophysical Research, v. 87, p. 8561–8569.

Donovan, R.N., Gilbert, M.C., Luza, K.V., Marchini, D., and Sanderson, D., 1983, Possible Quaternary movement on the Meers fault, southwestern Oklahoma: Oklahoma Geology Notes, v. 43, p. 124–133.

Eaton, G.P., 1979, A plate-tectonic model for late Cenozoic crustal spreading in the western United States, *in* Riecker, R.E., ed., Rio Grande rift: Tectonics and magmatism: Washington, D.C., American Geophysical Union, p. 7–32.

Evans, G.L., 1949, Upper Cenozoic of the High Plains, *in* Cenozoic geology of the Llano Estacado and Rio Grande Valley: Midland, Texas, West Texas Geological Society and New Mexico Geological Society Guidebook, p. 1–22.

Galusha, T., and Blick, J.C., 1971, Stratigraphy of the Santa Fe Group, New Mexico: American Museum of Natural History Bulletin, v. 144, p. 1–128.

Golombek, M.P., McGill, G.E., and Brown, L., 1983, Tectonic and geologic evolution of the Espanola Basin, Rio Grande rift: Structure, rate of extension, and relation to the state of stress in the western United States: Tectonophysics, v. 94, p. 483–507.

Gustavson, T.C., and Budnik, R.T., 1985, Structural influences on geomorphic processes and physiographic features, Texas Panhandle: Technical issues in siting a nuclear-waste repository: Geology, v. 13, p. 173–176.

Izett, G.A., 1975, Late Cenozoic sedimentation and deformation in northern Colorado and adjoining areas, *in* Curtis, B.F., ed., Cenozoic history of the southern Rocky Mountains: Geological Society of America Memoir 144, p. 179–209.

Kelley, V.C., 1979, Tectonics, middle Rio Grande rift, New Mexico, *in* Riecker, R.E., ed., Rio Grande rift: Tectonics and magmatism: Washington, D.C., American Geophysical Union, p. 57–70.

Kirkham, R.M., and Rodgers, W.P., 1981, Earthquake potential in Colorado—A preliminary evaluation: Colorado Geological Survey Bulletin 43, 171 p.

Larson, E.E., Patterson, P.E., Curtis, G., Drake, R., and Mutschler, F.E., 1985, Petrologic, paleomagnetic, and structural evidence of a Paleozoic rift system in Oklahoma, New Mexico, Colorado, and Utah: Geological Society of America Bulletin, v. 96, p. 1364–1372.

Miller, J.P., Montgomery, A., and Sutherland, P.K., 1963, Geology of part of the southern Sangre de Cristo Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 11, 106 p.

Morgan, P., and Golombek, M.P., 1984, Factors controlling the phases and styles of extension in the northern Rio Grande rift, *in* Baldridge, W.S., et al., eds., Rio Grande rift: Socorro, New Mexico, New Mexico Geological Society, 35th Field Conference Guidebook, p. 13–19.

Patton, L.T., 1923, The geology of Potter County: University of Texas, Austin, Bureau of Economic Geology and Technology Bulletin 2330, 180 p.

Reading, H.C., 1980, Characteristics and recognition of strike-slip fault systems, *in* Ballance, P.F., and Reading, H.G., eds., Sedimentation in oblique-slip mobile zones: International Association of Sedimentologists Special Publication 4, p. 7–26.

Sales, J.K., 1968, Crustal mechanics of [illegible] foreland deformation: A regional [illegible] model approach: American Association [illegible] leum Geologists Bulletin, v. 52, p. 201[illegible]

Schultz, G.E., 1977, The Ogallala Formation [illegible] vertebrate faunas in the Texas and O[illegible] panhandles, *in* Schultz, G.E., ed., [illegible] field conference on late Cenozoic bio[illegible] of the Texas Panhandle and adjacent O[illegible] West Texas State University Kilgore [illegible] Center Special Publication 1, p. 5–10[illegible]

Seager, V.R., Shafiqullah, M., Hawley, [illegible] Marvin, R.F., 1984, New K-Ar [illegible] basalts and the evolution of the [illegible] Grande rift: Geological Society of Ame[illegible] letin, v. 95, p. 87–99.

Seni, S.J., 1980, Sand-body geometry and [illegible] tional systems, Ogallala Formation, Tex[illegible] versity of Texas at Austin, Bureau of Ec[illegible] Geology Report of Investigations 105, 3[illegible]

Taylor, R.B., 1975, Neogene tectonism [illegible] central Colorado, *in* Curtis, B.F., ed., [illegible] history of the southern Rocky M[illegible] Geological Society of America Mem[illegible] p. 211–226.

Tedford, R.H., 1981, Mammalian biochrono[illegible] the late Cenozoic basins of New [illegible] Geological Society of America Bulletin [illegible] p. 1008–1022.

Tweto, O., 1979, The Rio Grande rift system [illegible] rado, *in* Riecker, R.E., ed., Rio Grande [illegible] tonics and magmatism: Washington [illegible] American Geophysical Union, p. 33–56.

——1980, Tectonic history of Colorado, *in* Ke[illegible] H.C., and Porter, K.W., eds., Colorado geolog[illegible] Denver, Colorado, Rocky Mountain Associa[illegible] of Geologists, p. 5–9.

ver Wiebe, W.A., 1930, Ancestral Rocky Moun[illegible] American Association of Petroleum Geolog[illegible] Bulletin, v. 14, p. 765–788.

Walper, J.L., 1970, Wrench faulting in the [illegible] continent: Shale Shaker, v. 21, p. 32–40.

Winkler, D.A., 1985, Stratigraphy, vertebrate paleo[illegible] tology, and depositional history of the O[illegible] Group in Blanco and Yellowhouse [illegible] northwestern Texas [Ph.D. thesis]: Austin, [illegible] versity of Texas, 243 p.

Zoback, M.L., Anderson, R.E., and Thompson, [illegible] 1981, Cainozoic evolution of the state of [illegible] and style of tectonism of the Basin and [illegible] province of the western United States: [illegible] Society of London Philosophical Transac[illegible] ser. A, v. 300, p. 407–434.

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