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REGIONAL STRUCTURAL TRENDS INFERRED FROM GRAVITY AND AEROMAGNETIC DATA IN THE NEW MEXICO-COLORADO BORDER REGION

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INTRODUCTION

Long-term efforts to provide aeromagnetic and gravity data for the Rio Grande rift have recently led to the publication of an aeromagnetic map of New Mexico (Cordell, 1984) and gravity maps of New Mexico (Keller and Cordell, 1984) and of the Rio Grande rift covering large parts of Colorado, New Mexico, and Texas (Cordell, Keller, and Hildenbrand, 1982). These maps provide both a synoptic perspective for the study of very large structures and a readily accessible data base for New Mexico Geological Society field excursions and other topical studies. Here, we present a residual Bouguer gravity map centered on the Espafiola—Taos—San Luis Basins section of the Rio Grande rift, and a corresponding aeromagnetic map for the New Mexico sector (digital data from Colorado are not yet available). Preliminary interpretations of these data suggest the presence of some remarkable structures which may record successive Laramide, Eocene, mid-Tertiary, and Neogene deformations. *The maps (Figs. 1, 2) appear in the front matter of this guidebook.*

AEROMAGNETIC DATA

The residual total-magnetic-intensity data shown in Figure 1 are taken directly from. Cordell (1984) where data reduction and compilation procedures are described. In the study area, the aeromagnetic data, responsive primarily to bodies of crystalline rock, reflect either Cenozoic igneous rocks or lithologic boundaries within Precambrian crystalline basement. Black lines in Figure 1 delineate boundaries between rocks of differing magnetization, and were drawn by means of a computer-based method described by Cordell and Grauch (1982, 1984). To an approximation, these lines delineate geologic contacts between rocks having differing percentages of magnetite. The magnetization-boundary lines are helpful in interpreting magnetic-contour data because, in these latitudes, magnetic anomalies tend to be skewed southward of their causative bodies, as is apparent from comparing magnetization boundaries with associated anomalies in Figure 1.

GRAVITY DATA

The gravity data used to produce Figure 2 are essentially those used by Cordell, Keller, and Hildenbrand (1982). Major sources of data were the Defense Mapping Agency, Cordell (1976a), and Davis (1979). Reduction procedures are discussed in Cordell, Keller, and Hildenbrand (1982). A reduction density of 2.67 gm/cc was used to produce the Bouguer-anomaly values. Terrain corrections for the region extending from 0.875 km to 166.7 km were calculated using the technique of Plouff (1977). In the study area, gravity data, responsive to variations in rock density, reflect low-density graben or sedimentary basin fill (gravity lows), basement-cored uplifts (gravity highs), and various intrabasement features giving rise to either lows or highs.

Deep crustal and upper-mantle structures, and their associated isostatic effects, produce a broad increase in regional gravity values from west to east across the study area, which obscures the more local anomalies of interest here. In order to remove this regional anomaly, a second-order polynomial surface was fitted to our gravity data in southern Colorado and northern New Mexico using the technique of Lance (1982). The residual-anomaly values, that is the Bouguer-anomaly values minus corresponding values on the second-order polynomial surface, are shown in Figure 2. Black lines delineating contacts between rocks having differing densities were computer-derived by a procedure similar to that used to determine the magnetization boundaries (Cordell, 1979; Cordell and Grauch, 1982, 1984).

DISCUSSION OF GEOPHYSICAL FEATURES BY INFERRED GEOLOGIC AGE

It is not a common practice to discuss potential field-geophysical features chronologically, because there is no time quality intrinsic to these data and because potential field effects of sources of different ages can be superimposed. However, we do so here because a chronological ordering provides the most straightforward presentation of our data and interpretations. The reasons for this are that these geophysical data seem exceptionally clearly correlative with major structural features, and a sense of the evolution of superimposed tectonic events in this region seems to be the key to understanding its present structural style. However, lest the reader unfamiliar with geophysical methods be misled by an historical format, we emphasize that these data are ambiguous, as are all potential field data. Alternative interpretations are possible, and the age and source depth of the anomalies may not be as we have supposed.

We believe from regional considerations that the northeast magnetic grain of the San Juan Basin (southwest quarter of Figure 2; see Cordell and Grauch, 1984), and perhaps the arcuate gravity high extending from Westcliffe through Walsenburg (Kleinkopf and others, 1970) reflect Precambrian structural trends. Geophysical expressions of other suspected Precambrian, Cambrian, and Pennsylvanian structures are difficult to relate to geologic structures formed at a particular time. Examples include the northwest-trending gravity high beneath the San Juan Basin (Lindrith to Farmington); the northeast-trending gravity and magnetic features in the Mora—Wagon Mound area; and the gravity lows related to sedimentary basin fill or, possibly, to unsuspected Precambrian felsic batholiths in the Mora and Weston areas. From Laramide (Late Cretaceous—Paleocene) time on, however, the geological story comes more sharply into focus, and we can try to see the development of the geophysical anomalies in that context.

Laramide structure in the region is characterized by west-to-east compression and thrusting sharply bounded on the east by a hogback monocline, thrust-sheet limit, or similar abrupt structural boundary. The trace of the Rocky Mountain front is delineated in Figure 2 by a short-dashed black line extending from the north border of Figure 2 near Goodpasture to the south border near Mora. This boundary in the New Mexico—Colorado border area is generally interpreted to be a zone of west-dipping, high-angle reverse faults (Grose, 1972; Tweto, 1975), and positive gravity anomalies over basement-cored uplifts in the Sangre de Cristo Mountains north of Fort Garland are consistent with this interpretation. However, south of Fort Garland, despite extensive areas of outcropping basement rocks, the gravity anomalies are transverse to the mapped Rocky Mountain front, a fact which is *not* consistent with the presence of thick basement blocks bounded by rooted, steeply dipping faults. Together, the gravity and geologic data suggest the existence of an extensive allochthonous terrane south of Fort Garland and east of Picuris (Pecos—Picuris fault) in southernmost Colorado and northern New Mexico, with sedimentary basins in the Mora and Weston areas (Raton Basin) extending westward beneath this terrane. Eastward-thrusted Precambrian rocks have been mapped in a few places east of Taos by Clark and Read (1972) and Reed and others (1983). Alternatively, the gravity patterns could be ascribed to combined effects of variable thick-

ness of Pennsylvanian and Permian strata and density variations within basement rocks, although this seems less likely given the data presently at hand.

In early Eocene time the region containing the Colorado Plateau moved north relative to the High Plains (Chapin and Cather, 1981, and cf. Hamilton, 1981). In New Mexico, displacement of 20 to 100+ km is thought to be distributed within a north—south zone of right-lateral shear-faulting about 100 km wide. The north—south-trending, partially right-slip Nacimiento fault (Baltz, 1967) near Cuba, New Mexico (in Fig. 2), and the Pecos—Picuris fault (Miller and others, 1963) are elements of this deformation. However, Miller and others interpreted strike—slip on the Pecos—Picuris fault as being primarily of Precambrian age. The Nacimiento falt is clearly delineated by both gravity and magnetic data, but the Pecos—Picuris fault is most clearly delineated by magnetic trends. Probably, more such faults are obscured by younger Neogene and Quaternary block-faulting and graben fill within the rift where any long, straight, north—south-trending Neogene normal fault can be suspected to be a reactivated early Eocene right-slip fault. The Nacimiento fault dies out north of Lindrith. It is difficult to accommodate much of strike—slip offset in Colorado along the Nacimiento fault trend because it crosses continuous gravity and structural positives that extend northwestward from the northern boundary of the Espafiola Basin. Precambrian fold axes are offset 38 km in a right-lateral sense along the PecosPicuris fault (Miller and others, 1963). We think this fault does *not* connect northward along the west side of the Taos—Questa Basin to the east side of the Alamosa (Colorado) gravity high and structural horst (Sutherland, 1972) primarily because the gravity data show the west side of the Taos—Questa graben to be zigzagged. If the Pecos—Picuris fault does extend northward into the Taos—Questa graben, it seems more likely that the Eocene fault controlled the *east* side of the Neogene Taos—Questa graben and that it dies out near the state border.

The aeromagnetic data of Figure 1 show a group of striking, blue-colored magnetic lows east and west of the rift, for which a palinspastic restoration, if valid, indicates a net 130 km offset along an early Eocene right-slip shear zone. The source of the blue anomalies is probably a thick sequence of Proterozoic quartzites and associated meta-supracrustal rocks which are common in northern New Mexico (Cordell and Grauch, 1984). East of the rift, the geologically mapped 38 km of right-lateral offset on the Pecos—Picuris fault is also clearly evidenced by an offset of the blue anomaly in the aeromagnetic data. A magnetization boundary almost exactly coincides with the mapped Pecos—Picuris fault, and the northeast-trending blue anomaly west of the fault at Pilar matches with the northeast-trending blue anomaly east of the fault headed north of Mora, allowing for the 38 km offset. A similar northeast-trending blue anomaly in the vicinity of Wagon Mound suggests another north-south-trending right-slip fault, similar to the Pecos—Picuris fault, in the vicinity of Mora. Restoring the offset on the Pecos—Picuris and inferred Mora faults, one can visualize a long, linear, northeast-trending blue anomaly east of the rift, similar to the long, northeast-trending blue anomaly to the west (Fig. 1), but seemingly displaced from it, again in a right-lateral sense. The sum of all the perceived displacements is about 130 km. Conceivably, the repetition of blue anomalies east of the rift could be explained as —30 km wave-length synformal infolds of quartzite and other weakly magnetic rocks in an isoclinal Precambrian terrane. However, this alternative interpretation would seem to be inconsistent with the mapped strike—slip displacement of Precambrian rocks along the Pecos—Picuris fault. Eocene deformation, manifested as north—south right slip in northern New Mexico, shows a component of folding in southern Colorado, which is consistent with an Euler pole in the Texas panhandle (Hamilton, 1981). Taken together, gravity and geologic data show a scalloped pattern along the east edge of the basement-cored uplifts, with southeast-plunging synclines in the Canyon City area (north of the north border of Figure 2 in the vicinity of Goodpasture), up the Wet Mountains Valley at Westcliffe, and, in light of preceding discussion, possibly up the San Luis Valley.

During Oligocene time the region was subjected to subduction-related magmatism and back-arc extension to the west—southwest (Eaton, 1980; Lipman, 1981). A salient, possibly Oligocene-age geophysical feature of the region is the gravity low associated with the San Juan Mountains batholith, marked by the large blue spot in the northwest quarter of Figure 2. Density boundaries show this feature to be about 70 km long and 25 km wide, and possibly contained within a larger gravity low about 160 km long and 70 km wide. To the extent that the gravity anomaly and gradients delineate an enormous volume of material of initially low viscosity hydraulically into the crust, these data require a mid-Tertiary episode during which the horizontal component of least principal stress (the extension direction) was north—south. This configuration is contrary to expectation and we have no explanation for it except to speculate that it could reflect a relaxation of the earlier, Eocene north—south compression.

Neogene and Quaternary-age geophysical anomalies are manifested gravity lows over low-density graben fill along the axis of the rift, and local gravity and magnetic anomalies over intrusive rocks. A broad gravity positive is present everywhere along the axis of the rift and provides a measure of crustal thinning and extension (Cordell, 1982). However, this anomaly decreases in width and magnitude northward, and in the region of Figure 2 becomes difficult to distinguish from gravity highs over basement uplifts. The very broad gravity low associated with the structure of the lithosphere—asthenosphere boundary (Ander, 1980) is largely removed from the data of Figure 2 in the course of removing the 2nd-degree polynomial "regional" field.

As elsewhere along the rift (Cordell, 1976b), the graben borders as defined by geophysical data follow an overall linear trend. However, in detail these borders zigzag complexly along segments typically 5-25 km in length, aligned in many cases with Precambrian structural grain. The fault at Pilar represents an east—northeast-trending, transform-like offset of the Espatiola and Taos—Questa grabens (Muehlberger, 1979). In the Taos—Questa area the *west* border of the graben is approximately along the Rio Grande, resulting in a much narrower graben than one would expect driving across the valley. A similarly narrow graben continues north—northwest to Mineral Hot Springs and beyond. The San Luis Valley section of the rift is discussed elsewhere in this guidebook by Keller and others. Here again, the graben is considerably narrower than the topographic valley.

REFERENCES

Ander, M. E., 1980, Geophysical study of the crust and upper mantle beneath the central Rio Grande rift and adjacent Great Plains and Colorado Plateau: Ph.D. dissertation, University of New Mexico, Albuquerque, 218 pp.; and Los Alamos National Laboratory publication LA-8676-T.

Baltz, E. H., 1967, Stratigraphy and regional tectonic implications of part of Upper Cretaceous and Tertiary rocks, east-central San Juan Basin, New Mexico: U.S. Geological Survey, Professional Paper 552, 101 pp.

Chapin, C. E., and Cather, S. M., 1981, Eocene tectonics and sedimentation in the Colorado Plateau—Rocky Mountain area; *in* Dickinson, W. R., and Payne, W. D. (eds.), Relations of tectonics to ore deposits in the southern Cordillera: Arizona Geological Society Digest, v. 14, pp. 173-198.

Clark, K. F., and Read, C. B., 1972, Geology and ore deposits of the Eagle Nest area, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 94, 152 pp.

Cordell, L., 1976a, Preliminary complete Bouguer anomaly gravity map of the Taos Basin section of the Rio Grande graben: U.S. Geological Survey Open-file map, scale 1:250,000.

_, 1976b, Aeromagnetic and gravity studies of the Rio Grande graben in New Mexico between Belen and Pilar: New Mexico Geological Society, Special Publication 6, pp. 62-70.

_, 1979, Gravimetric expression of graben faulting in Santa Fe country and the Espanola Basin, New Mexico: New Mexico Geological Society, Guidebook 30, pp. 59-64.

_, 1982, Extension of the Rio Grande rift: Journal of Geophysical Research, v. 87, pp. 8561-8569.

_, 1984, Composite residual total intensity aeromagnetic map of New Mexico: National Oceanic and Atmospheric Administration, National Geophysical Data Center, scale 1:500,000.

_, and Grauch, V. J. S., 1982, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico: extended abstract; *in* Society of Exploration Geophysicists, 1982 Annual Meeting, Abstracts with Programs, pp. 246-247.

_, and , 1984, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico: Geophysics, special issue on potential field methods, in press.

_____, Keller, G. R., and Hildenbrand, T. G., 1982, Bouguer gravity map of the Rio Grande rift: U.S. Geological Survey, Geophysical Investigations Map GP-949, scale 1:1,000,000.

Davis, G., 1979, A gravity study of the San Luis Basin, Colorado: M.S. thesis, University of Texas at El Paso, 101 pp.

Eaton, G. P., 1980, Geophysical and geological characteristics of the crust of the Basin and Range province; *in* Continental tectonics: National Academy of Science, Washington, D.C., pp. 96-113.

Grose, L. T., 1972, Tectonics; *in* Mallory, W. W. (ed.), Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, pp. 34-44.

Hamilton, W., 1981, Plate-tectonic mechanism of Laramide deformation: University of Wyoming, Contributions to Geology, v. 19, pp. 87-92.

Keller, G. R., and Cordell, L., 1984, Bouguer gravity anomaly map of New Mexico: National Oceanic and Atmospheric Administration, National Geophysical Data Center, scale 1:500,000.

Kleinkopf, M. D., Peterson, D. L., and Johnson, R. B., 1970, Reconnaissance geophysical studies of the Trinidad quadrangle, south-central Colorado; *in* Geological Survey Research 1970: U.S. Geological Survey, Professional Paper 700-B, pp. B78—B85.

Lance, J. 0., Jr., 1982, Frequency domain analysis of least-square polynomial surfaces with application to gravity data in the Pedregosa Basin area: Ph.D. dissertation, University of Texas at El Paso, 190 pp.

Lipman, P. W., 1981, Volcano-tectonic setting of Tertiary ore deposits, southern Rocky Mountains; *in* Dickinson, W. R., and Payne, W. D. (eds.), Relations of tectonics to ore deposits in the southem Cordillera: Arizona Geological Society Digest, v. 14, pp. 199-213.

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 1, 106 pp.

Muehlberger, W. R., 1979, The Embudo fault between Pilar and Arroyo Hondo, New Mexico: an active intracontinental transform fault: New Mexico Geological Society, Guidebook 30, pp. 77-82.

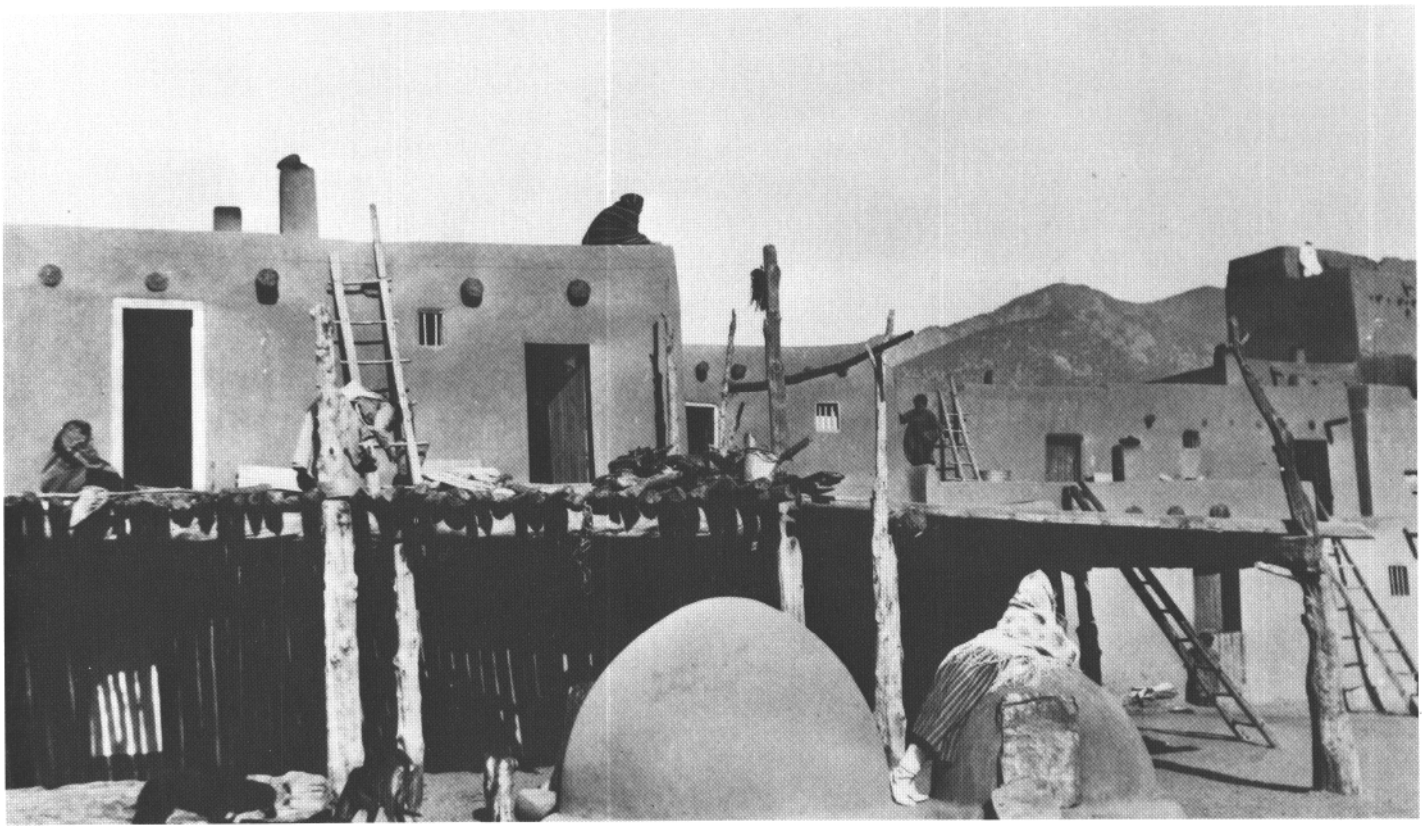
Plouff, D., 1977, Preliminary documentation for a Fortran program to complete gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geological Survey, Open-file Report 77-535, 45 pp.

____, and Pakiser, L. C., 1972, Gravity study of the San Juan Mountains, Colorado: U.S. Geological Survey, Professional Paper 800-B, pp. B1P3—B190.

Reed, J. C., Lipman, P. W., and Robertson, J. R., 1983, Geologic map of the Latir Peak and Wheeler Peak Wildernesses and Columbine—Hondo Wilderness Study Area, Taos County, New Mexico: U.S. Geological Survey, Map MF-l570-B, scale 1:50,000.

Sutherland, P. K., 1972, Pennsylvanian stratigraphy, southern Sangre de Cristo Mountains, New Mexico; *in* Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, pp. 139-142.

Tweto, 0., 1975, Laramide (Late Cretaceous—early Tertiary) orogeny in the southem Rocky Mountains; *in* Cenozoic history of the Southern Rocky Mountains: Geological Society of America, Memoir 144, pp. 1-44.



Taos Pueblo, ca 1920. Photo by Burt Harwood.