Exotic blocks within the early Tertiary Rubio Peak Formation in the north-central Black Range, New Mexico: Occurrence, insights into post-emplacement tectonic activity, economic implications and emplacement hypothesis

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EXOTIC BLOCKS WITHIN THE EARLY TERTIARY RUBIO PEAK FORMATION IN THE NORTH-CENTRAL BLACK RANGE, NEW MEXICO: OCCURRENCE, INSIGHTS INTO POST-EMPLACEMENT TECTONIC ACTIVITY, ECONOMIC IMPLICATIONS AND EMPLACEMENT HYPOTHESIS

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Abstract—Exotic blocks of Pennsylvanian limestone-shale lithology occur within volcaniclastic deposits of the lower Rubio Peak Formation (early Tertiary) over a region of 180 km^2 in the north-central Black Range, New Mexico. Known surface area of these blocks exceeds 10.1 km^2, thickness averages 120 m, giving a minimum volume of 1.2 km^3. These allochthonous blocks are believed to have been emplaced by gravity-sliding during Eocene time. The blocks were accompanied by relatively minor additional slide material and came to rest upon a relatively flat surface. Bedding within the largest exotic blocks is parallel to this slide surface. Both massive, poorly bedded sandstone-siltstone deposits and heterolithic, limestone-poor, debris-flow deposits underlie and engulf the exotic blocks. Based on a preferred northwest-southeast strike orientation of clastic dikes, lithologic characteristics and flow-direction indicators, the exotic blocks' detachment area is interpreted to have been to the southwest of their present position. Because of their unique geometries and distinctive lithologies, the exotic blocks can be used to document and measure displacement on crosscutting structures that have resulted from post-emplacement tectonic events. In particular, restoring the largest exotic blocks to assumed original geometry indicates that at least 3.14 km of dextral strike-slip displacement has occurred on four structures; this faulting is part of a wide and extensive Eocene wrench-fault system active along the eastern margin of the Colorado Plateau. Furthermore, the exotic blocks made a distinctive marker horizon that aids in documenting normal faulting related to the earliest development of the Rio Grande rift in southwestern New Mexico. Open-space development and brecciation created by deflection of normal-fault attitudes cutting downward through the exotic blocks is an important structural control in localizing economic mineral deposits. It is hypothesized that late Laramide wrench-fault activity along the Santa Rita–Hanover axis, southwest of the exotic-block occurrences, produced local uplifts and possibly steep escarpments from which large segments of Pennsylvanian strata detached and slid under the force of gravity toward the northeast.

INTRODUCTION

During the New Mexico Geological Society's 1986 Fall Field Conference, Stops two and three of the first-day road tour (Osburn et al., 1986) visited a geologically intriguing area where rather large blocks of Pennsylvanian strata rested upon and were overlain by volcaniclastic deposits of the early Tertiary Rubio Peak Formation. Little was offered in explanation of this phenomenon, other than that these allochthonous blocks were probably of gravity-slide derivation, with an unknown area of origin. The idea of gravity-slide emplacement was first suggested by Maxwell and Heyl (1976) and later adopted by Harrison (1986) from preliminary studies. Chapin et al. (1978) noted the nature of these "detached raft-like masses" and the absence of any nearby similar section. This article provides a description of occurrences of the exotic blocks, interprets the geologic history recorded in these deposits and presents a hypothesis regarding their origin.

OCCURRENCES

Exotic blocks of Pennsylvanian strata crop out over an area in excess of 180 km^2 in the north-central Black Range, New Mexico. More than 50 individual blocks occur within this area, ranging from room-size to gigantic masses with surface areas greater than 1 km^2 and thicknesses of up to 150 m. They have an accumulative outcrop area of about 10.1 km^2, an average thickness of 120 m, and a minimum volume of 1.2 km^3. From underground mining activity, it is known that additional, large exotic blocks occur buried in the subsurface.

The area containing the greatest number of exotic-block occurrences, as well as the largest blocks, is located southwest and west of the Chloride and Winston townsites (Fig. 1). A cluster of smaller blocks

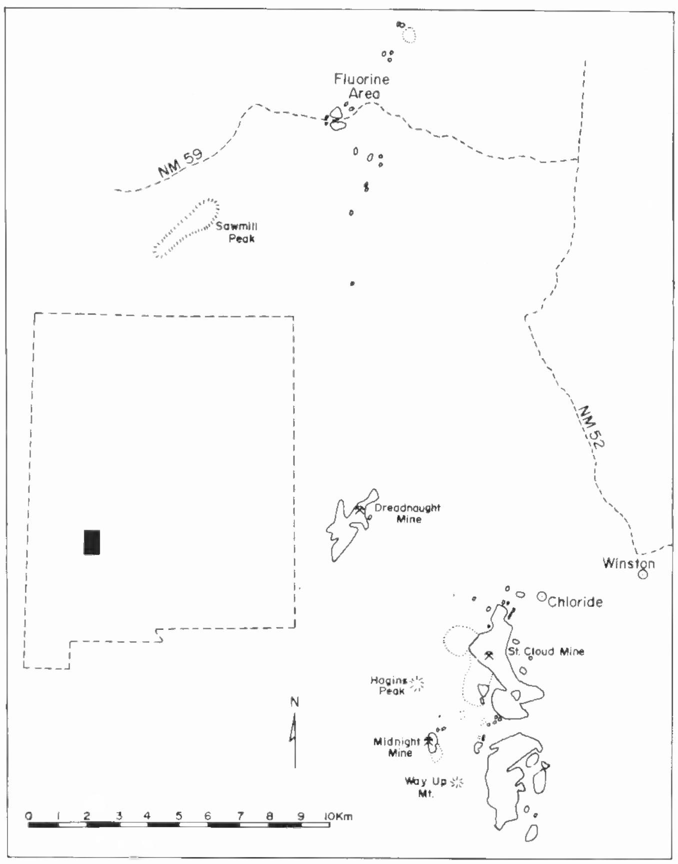

FIGURE 1. Known occurrences of exotic, Pennsylvanian limestone blocks in the north-central Black Range of New Mexico. Large blocks in the southern area are as much as 150 m thick; all blocks are found within the lower Tertiary Rubio Peak Formation. Solid lines enclose outcrops, dotted lines outline known extents of buried blocks.

occurs northward in the Fluorine area, where the largest blocks are about 60 m thick. The large block around the Dreadnaught mine is isolated from other exotic-block occurrences by surrounding, younger graben structures (Harrison, 1986) that have down-dropped the slide horizon.

All of the exotic blocks occur at a single stratigraphic horizon within the lower Tertiary Rubio Peak Formation. This horizon is located near the middle of an 800-m-thick sequence of volcaniclastic sediments, composed of interfingering sandstone and debris-flow deposits. Except for the exotic-block horizon and sparse, isolated patches of limestone boulders shed from the large blocks, this sequence of volcaniclastic sediments contains no limestone lithologies.

Both sandstone and debris-flow deposits are massive, largely non-graded and lack any prominent stratigraphic marker intervals. The identical nature of volcaniclastic deposits above and below the exotic-block horizon indicates that the blocks were emplaced without disruption of established sedimentary patterns. The high-preservation state of the exotic blocks and the sparseness of their lithology in surrounding epiclastic deposits suggests that the blocks were buried rather rapidly. A schematic stratigraphic section containing the exotic block horizon is presented in Figure 2.

Age-date constraints suggest that the lower Rubio Peak Formation, which hosts exotic block occurrences, was deposited largely during the Eocene epoch. The first-dated overlying rocks are in the upper Rubio Peak Formation, where Lucas (1986) found paleontologic species (*Jaywilsonomys ojinagaensis* and *Montanatylopus matthewi*) that he estimates to be 36 Ma old in volcaniclastic beds that are separated from the exotic-block horizon by several hundred meters of volcaniclastic and volcanic section, including a few discontinuities. McIntosh et al. (1986) give an $^{40}Ar/^{39}Ar$ date of 35.3 my for the Kneeling Nun Tuff, directly overlying the Rubio Peak Formation. Jahns et al. (1978) and McMillan (1979) believed that rocks of the lower Rubio Peak Formation in the adjacent Sierra Cuchillo Range had already been deposited when a monzonite laccolith, dated by K-Ar at 50 my (Chapin et al., 1975), intruded that area. In the Santa Rita area, about 60 km south-southwest of exotic-block occurrences, rocks of the Rubio Peak Formation unconformably overlie porphyry copper deposits (Elston, 1976) dated by K-Ar at 57–59 my (McDowell, 1971). Intrusive and extrusive rocks within the Rubio Peak Formation in the southern Black Range have yielded K-Ar dates generally ranging from 37–45 my (Seager et al., 1982).

The larger exotic blocks in the area of the Dreadnaught–St. Cloud–Midnight mines consist of intercalated limestone and shale beds ranging from 3–10 m thick. Limestone varieties are micrite and spar; shale deposits occur as both black, moderately well-consolidated and green, poorly consolidated material; both limestone and shale beds are very fossiliferous, containing brachiopods, crinoids, bryozoans and fusulinids. Limestone is fetid and commonly contains horizons of black chert. Shale beds commonly contain rounded cobbles of limestone. Clastic/limestone ratio for the larger exotic blocks is about .40, sandstone/shale ratio is about .05 (see Table 1). Bedding-plane attitudes within the larger exotic blocks are always parallel to the base of the blocks (i.e., slide surface).

Most generally, the larger exotic blocks lie directly upon volcaniclastic rocks with sharp contact. Locally, however, relatively small breccia deposits containing volcanic and limestone clasts, with occasional pieces of petrified wood, exist for a few meters below the blocks' base. Similar rocks also occur in irregular, channel-shaped deposits around the margins of the larger exotic blocks. Limestone blocks within these breccia deposits range up to 10 m in diameter and frequently display chaotic, steeply dipping attitudes.

In sparse patches along the base of larger exotic blocks, deformed shale beds containing isolated volcanic breccia fragments grade downward into thin (about 0.5 m thick) breccia zones that show features interpreted as indicative of flowage and fragment rolling. These breccias consist of subrounded to subangular, millimeter- and centimeter-sized fragments supported by a wispy, layered matrix of very fine-grained, broken and granulated cataclastic material. Such breccia material, exposed by underground workings of the St. Cloud mine, contains cigar-shaped fragments that are strongly elongated in a northwest-southeast direction.

Two types of clastic dikes intrude upward into the exotic blocks: heterolithic (volcanic-limestone) breccia dikes and medium-grained, sandstone dikes. Breccia dikes are more abundant, as much as 10 m wide, and intrude as far as 100 m upward. They are generally near-vertical, more numerous and wider in shale horizons and preferentially oriented in a northwest-southeast direction (Fig. 3). Sandstone dikes occur only where limestone blocks directly overlie sandstone deposits; such dikes are generally small and lack preferred orientation.

POST-EMPLACEMENT TECTONIC IMPLICATIONS

Because of their unique geometric shapes and distinctive lithology, the exotic blocks serve as stratigraphic markers within the otherwise monotonous, thick sequence of volcaniclastic rocks. As such, they aid in the documentation and measurement of some post-emplacement tectonic events that occurred in the north-central Black Range. In particular, information on Eocene north-northeast-trending wrench faulting

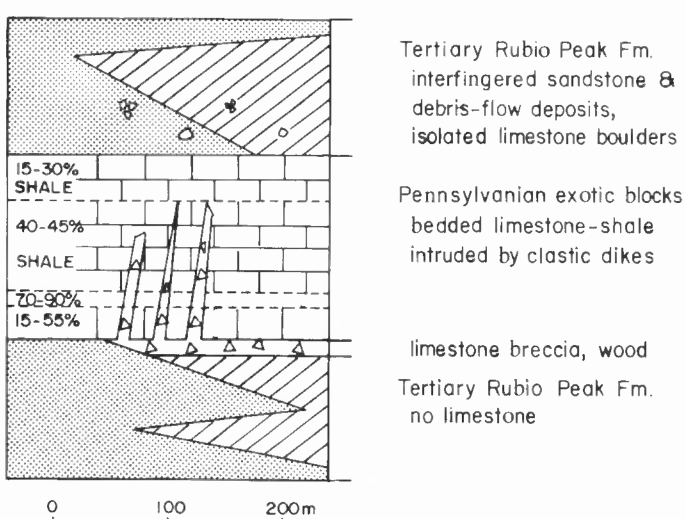

FIGURE 2. Schematic stratigraphic section showing exotic-block and surrounding horizons; dotted pattern represents sandstone, lined pattern represents debris-flow deposits.

TABLE 1. Comparisons of thicknesses, clastic/limestone ratios and sandstone/shale ratios of exotic Pennsylvanian limestone blocks in the north-central Black Range and surrounding, in-place Pennsylvanian sections; exotic blocks from this report, all other data from Kottlowski (1960).

Area	Thickness	Clastic\ Limestone	Sandstone\ Shale
Exotic blocks	160 m	.40	.05
Sierra Cuchillo	460 m	.14	.75
Hermosa	490 m	.20	.70
Kingston	220 m	.51	.15
Mimbres	325 m	.56	.02
Santa Rita	279 m	.59	.02
Silver City	30 m	.35	0

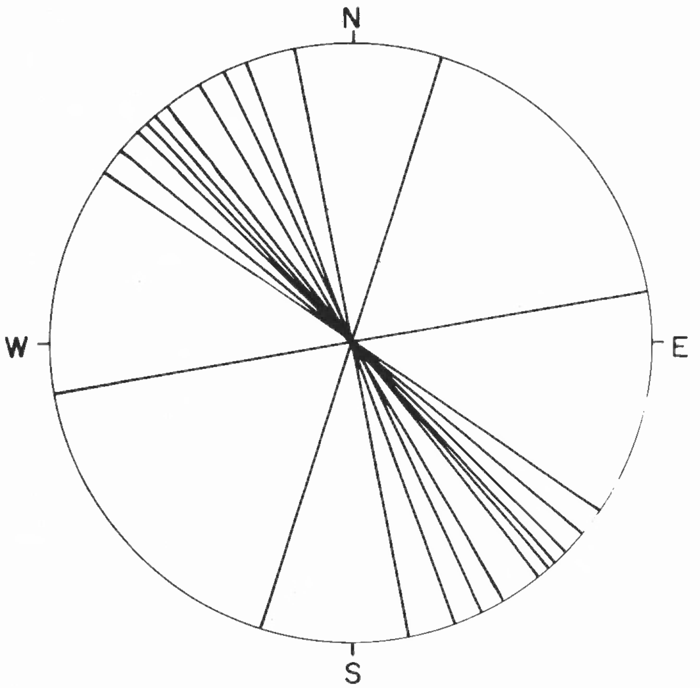

FIGURE 3. Orientation diagram for clastic dikes that intrude upward into exotic blocks; each line represents the strike of one dike.

and late Oligocene–early Miocene, northwest-trending normal faulting is gained from analyzing offsets in the exotic blocks.

Eocene wrench faulting

Chapin and Cather (1981) and Chapin (1983) described the existence and importance of right-lateral wrench faulting along the eastern margin of the Colorado Plateau during an Eocene stage of the Laramide orogeny. Harrison (1987) reported that strands of this wrench-fault system cut rocks of the lower Rubio Peak Formation in the north-central Black Range, offsetting exotic blocks.

Geometric analysis of exotic blocks reveals that they have been horizontally fragmented and reoriented by wrench-fault activity. Figure 4A shows the present outcrop pattern of the exotic blocks and known, major wrench faults in an area around the St. Cloud and Midnight mines (from Harrison, 1989); Figure 4B shows a reconstruction of exotic-block geometry after removing approximately 3140 m of dextral strike slip from four structures. Note that this movement not only aligns the northern edges of the large exotic blocks, but also juxtaposes smaller blocks containing distinctive breccia textures. Thus, two piercing points are re-aligned with one motion. Originally, the exotic blocks are believed to have existed as a single, more-compact mass, slightly elongated in a northwest-southeast direction.

Late Oligocene–early Miocene normal faulting

The earliest phase of Cenozoic extensional tectonism in southwestern New Mexico developed northwest-trending basins and uplifts, during the late Oligocene–early Miocene (Chapin and Seager, 1975; Seager et al., 1984). High-angle and listric normal faults belonging to this phase

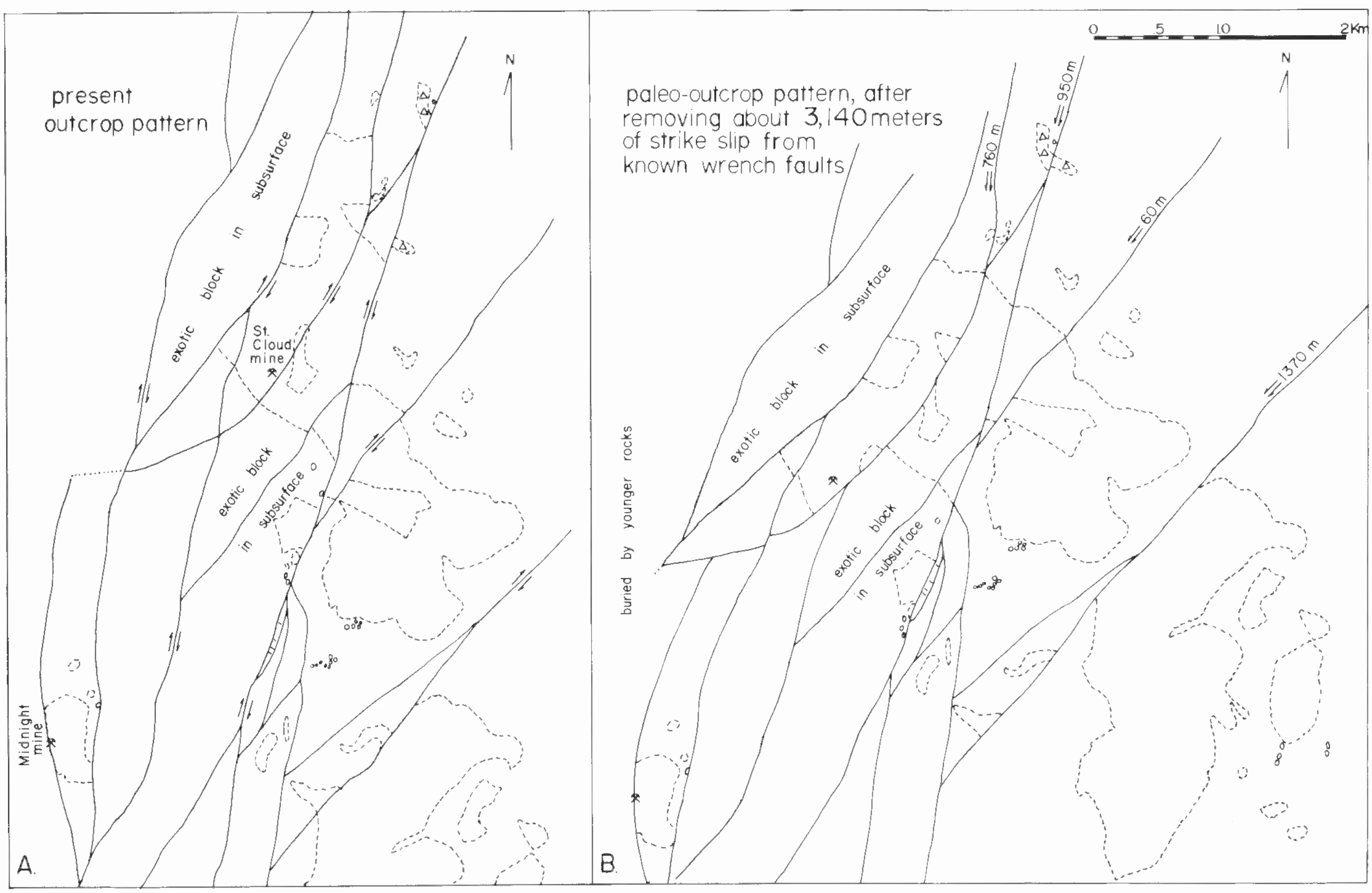

FIGURE 4. Planar analysis of exotic-block geometries in the St. Cloud–Midnight mines area. A, Present outcrop pattern of exotic blocks and major, known wrench faults. B, Paleo-outcrop pattern after removing approximately 3140 m of dextral strike slip from four wrench structures.

of deformation are found throughout the north-central Black Range, most commonly containing veins of epithermal, quartz-calcite(-sulfide) mineralization dated by K-Ar at about 26 my (Harrison, 1986).

The greatest insight into the amount of vertical separation along these structures is provided by offsets in the exotic blocks. Without the occurrence of these blocks as a distinctive stratigraphic horizon, it would be impossible to make estimates of the magnitude of faulting. A northeast-southwest cross section, through a portion of the large exotic block occurring in the vicinity of the St. Cloud mine, is shown in Figure 5. This cross section is generated from surface expressions, exposures in mine workings and exploration diamond-drilling. With the aid of the marker horizon, a prominent, northeast-facing, half-graben structure is displayed with about 150 m of stratigraphic separation on the master-fault system (Schmitt veins). Antithetic structures (such as St. Cloud and Mary Ann veins) occur as high-angle, normal faults with as much as 70 m of stratigraphic separation. Strikes of the master-fault system and antithetic faults are nearly perpendicular to cross section.

ECONOMIC IMPLICATIONS

Any discussion of exotic block occurrences in the north-central Black Range is incomplete without mentioning the implications for economic geology. The highest-grade and largest-tonnage silver-copper-gold deposits of the Chloride mining district are found where epithermal veins cut through the exotic blocks. Although other structural features, such as intersections between wrench faults and veins, are also very important in controlling locations of mineralization in this district (Harrison, 1988a), vein-filled faults at the base of the exotic blocks are locally unprecedented in mineral accumulation.

Because of differing rock strengths and bedding characteristics between the exotic blocks and surrounding volcaniclastic sediments, faults commonly change dip angle when they pass from one lithology into another. In general, high-angle faults flatten when they enter the exotic blocks and then steepen when they pass downward into the massive volcaniclastic deposits. The open-space (now filled with vein material) and brecciation occurring at these deflection sites localized heavy concentrations of sulfide mineralization and were termed "favorable zone" at the St. Cloud mine by Freeman and Harrison (1984).

Cross sections for three mineralized vein systems that displace exotic blocks are shown in Figure 6 (A: St. Cloud mine, L-2 stope; B: Dreadnaught mine; C: Lucky Friday vein, Fluorine area). In this figure, black areas contain high concentrations of precious and base metal mineralization; unpatterned rocks are massive, volcaniclastic sandstone and debris-flow deposits of the lower Rubio Peak Formation. Note that the more acute the angle is between bedding and faulting, the greater the degree of fault deflection, vein complexity and development of open space.

In addition to this physical control on economic mineral location, exotic blocks also appear to have exerted a chemical control on mineral deposition. Geochemical modeling suggests that most mineral deposition in the Chloride mining district was the result of mixing between near-surface meteoric waters and upwelling, metal-bearing hydrothermal solutions (Behr, 1988). In the resulting complex-sulfide deposits, the dominant ore mineralogy is an assemblage of high-silver- and high-copper-bearing species; deposition of these species is greatly enhanced by the high-pH conditions expected of waters in equilibrium with the carbonate-rich exotic blocks (Harrison, 1988b).

DISCUSSION AND INTERPRETATION OF TRANSPORT DIRECTION AND DETACHMENT AREA

The preliminary interpretation of Maxwell and Heyl (1976) and Harrison (1986), that the exotic blocks in the north-central Black Range are of gravity-slide derivation, is still maintained. The fact that these blocks rest upon both sandstone and debris-flow deposits effectively rules out emplacement via rafting on top of a massive debris flow. Indeed, exotic-block emplacement appears to have been the result of a catastrophic event unrelated to existing depositional processes. Most

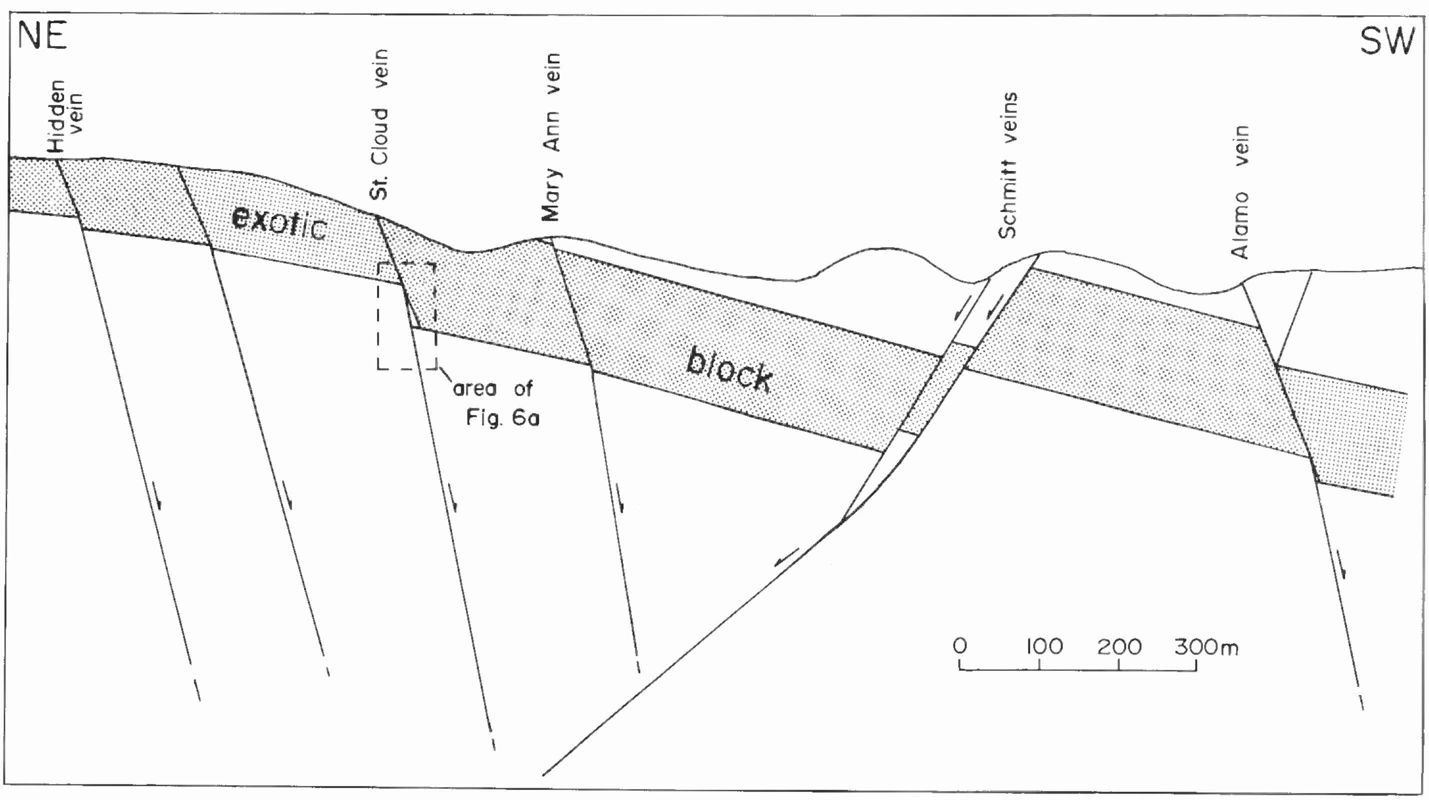

FIGURE 5. Northeast-southwest cross section in the vicinity of the St. Cloud mine; rocks overlying and underlying the exotic block are monotonous debris-flow breccias and massive sandstone in the Rubio Peak Formation. The exotic-block horizon aids in defining a northeast-facing half-graben structure, with a strike nearly perpendicular to section. The master fault system (Schmitt veins) is listric in nature and shows a stratigraphic separation of about 150 m; antithetic faults (such as Hidden, St. Cloud and Mary Ann veins) are high-angle and normal, with as much as 70 m of stratigraphic separation. The dashed box is blowup in Figure 6A.

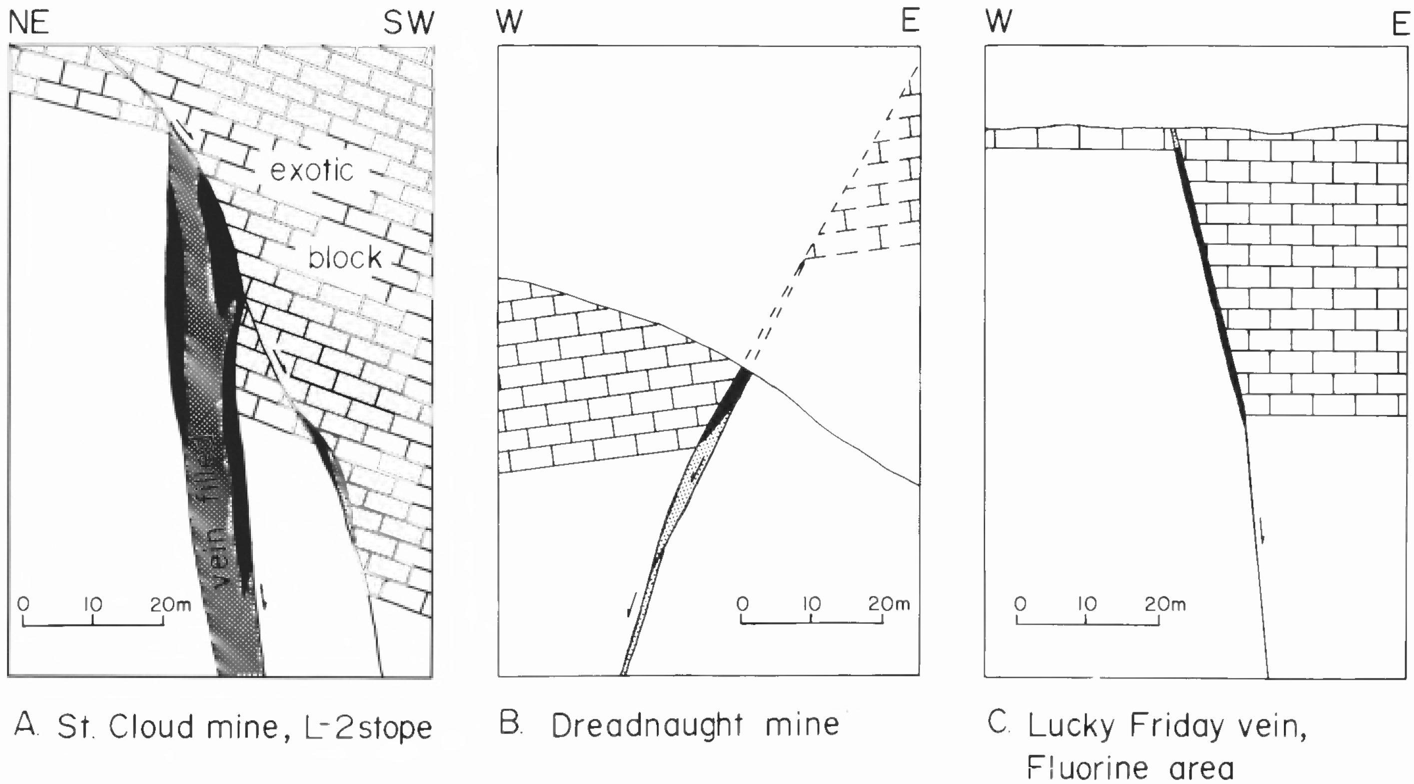

FIGURE 6. Cross sections for three mineralized vein systems that displace exotic blocks. A, St. Cloud mine, L-2 stope. B, Dreadnaught mine. C, Lucky Friday vein, Fluorine area. Blackened areas contain high concentrations of precious and base metals; unpatterned rocks are massive, volcaniclastic sandstone and debris-flow deposits.

of the relatively minor material that accompanied the large blocks in transport was injected upward into stress fractures and preserved as clastic dikes. It is envisioned that shale beds acted influentially in detachment and transport, but were almost totally smeared out in the blocks' wake.

Such gravity-slide events are essentially composed of detachment, transport and deposition (stopping). Under the force of gravity, a critical slope development (function of coefficient of friction) is all that is required for detachment to occur (DeSitter, 1954), however, pore-fluid lubrication and escarpment formation greatly facilitate detachment (Hubbert and Rubey, 1959; Chapman, 1979). Once detached, a slide-block will remain in transport until its momentum is reduced to zero. Slope and friction are the most important factors governing momentum attrition. If a mass behaves as a relatively coherent, strong, brittle block, then its detachment can be modeled as the basic inclined-plane problem of physics.

While a gravity-slide block is in transport, its internal stresses are similar to those of a thrust block, with maximum principal stress oriented nearly horizontal and in the direction of motion, intermediate principal stress oriented horizontal and perpendicular to motion and least principal stress oriented near vertical (Hafner, 1951; Chapman, 1979; Suppe, 1985). Direction of maximum principal stress is determined solely by down-slope direction and is independent of crustal stress fields.

Corresponding Coulomb failure trajectories are then predicted in two sets, one at an acute angle to horizontal and one at a steep angle to horizontal, both parallel to and containing the intermediate stress direction (Hafner, 1951). The clastic dikes found intruding upward into the exotic blocks are interpreted as fracture fillings that developed during block transport in response to sliding stresses. As such, their strike direction defines the intermediate stress direction and is oriented perpendicular to transport. These are mainly oriented northwest-southeast (Fig. 3), implying that the exotic blocks were transported from either the northeast or the southwest.

Similar conclusions are drawn from two other observations. First, rounded fragments within the cataclastic material located at the base of the exotic blocks in the St. Cloud mine are also elongated in a northwest-southeast direction. Axial lengths of these fragments are four to five times greater than their cross-sectional diameters. In a rolling or gliding environment at the base of sliding blocks, elongation is expected to be in an orientation perpendicular to transport direction. Secondly, north-northeast-trending, mullion-like structures occur along the base of the exotic block surrounding the Dreadnaught mine. Such features should be basically parallel to transport direction.

Three lines of evidence suggest that the exotic-block's detachment area was to the southwest of their present position and not to the northeast. First, lithological characteristics of the exotic blocks are similar to those of Pennsylvanian strata lying to the southwest, but are very different from Pennsylvanian strata found to the northeast. Table 1 lists clastic/limestone and sandstone/shale ratios for the exotic blocks and for surrounding Pennsylvanian sections from Kottlowski (1960); Figure 7 shows the relative positions of these sections. Sections in the Sierra Cuchillo Range and southern San Mateo Mountains are to the northeast of exotic-block occurrences, and sections in the Mimbres Valley, Santa Rita and Silver City areas are to the southwest.

Secondly, from the sedimentary record, there does not appear to have been any source outcrop area for Pennsylvanian strata to the northeast of the exotic-block occurrences. Regional facies changes within the volcaniclastic rocks that host the exotic blocks indicate a drainage from the northeast quadrant (debris-flow ⟶ fluvial sandstone ⟶ lacustrine deposits; Harrison, in prep.); and these rocks are virtually devoid of any limestone lithologies. Exotic blocks were brought in from an area outside of established sedimentary patterns and without disruption of these patterns, eliminating the northeast quadrant as a source area.

Finally, although cataclastic material is extremely sparse along the base of the exotic blocks, the small amount of material of this kind found in the St. Cloud mine contains impact features, pressure shadows and other flowage indicators suggesting a southwest to northeast trans-

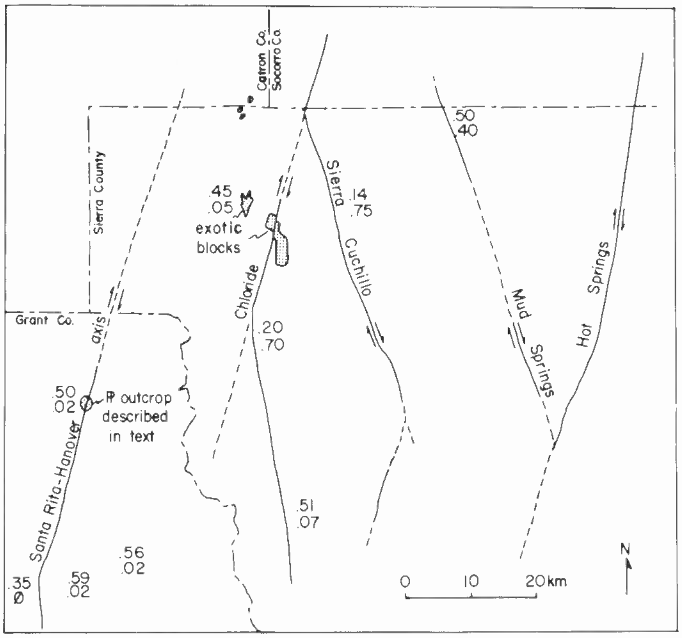

FIGURE 7. Generalized location map of south-central New Mexico showing relative positions of exotic blocks, known or suspected wrench faults, Pennsylvanian outcrop on the Santa Rita–Hanover axis and clastic/limestone (upper numbers)—sandstone/shale (lower numbers) for sections listed in Table 1. Dashed extensions of wrench faults are segments largely covered by younger rocks.

port direction. Unfortunately, similar material indicative of motion direction is not known to exist elsewhere.

EMPLACEMENT HYPOTHESIS

My emplacement hypothesis is strongly influenced and biased by the idea that the exotic blocks were emplaced during the Eocene epoch, when wrench-fault activity was a dominant tectonic style along the eastern margin of the Colorado Plateau, particularly along north-northeast- and north-northwest-trending structures. My work in south-central New Mexico over the past few years has lead me to believe that Eocene-aged wrench faulting occurred in this area across a wide zone, with individual strands extending from the western front of the Caballo–Fra Cristobal Mountains westward through the area containing the exotic blocks (Harrison, in prep.). My interpretation is that this zone continued even farther west, along structures now largely buried beneath younger rocks of the Mogollon-Datil volcanic field. Early Tertiary tectonism along one of these buried structures, known as the Santa Rita–Hanover axis, is hypothesized as being responsible for exotic-block detachment.

Certainly, other forms of tectonism besides wrench faulting, and even volcanism, can produce conditions favorable for gravity sliding of large exotic blocks. The ideas presented here may not be totally convincing. They are, however, very feasible, fit the observed geologic phenomena and are worthy of suggestion and consideration.

Early Tertiary wrench faulting

Chapin and Cather (1981) and Chapin (1983) describe early Tertiary, right-lateral wrench faulting along the eastern margin of the Colorado Plateau extending from southern Wyoming, southward through Colorado and into central New Mexico. This faulting occurred across a wide zone containing several fault strands, with as much as 100 km of accumulative horizontal displacement (Chapin, 1983).

Germane to my argument is the evidence supporting the southward continuation of Chapin and Cather's wrench-fault zone. Table 2 outlines criteria for known and suspected occurrences of individual, wrench-fault structures belonging to this zone in south-central New Mexico, and Figure 7 shows their generalized locations. More detailed descriptions of these structures will be presented elsewhere (Harrison, in prep.).

TABLE 2. Known or suspected early Tertiary wrench faults in south-central New Mexico; Figure 7 shows their generalized locations.

Location	Wrench-fault criteria
1) Hot Springs fault:	R' shears; oblique-angle fold (Cutter sag); remnant positive flower structure (thin-skinned deformation of Nelson and Hunter, 1986); nearly right-angle juxtaposition of north-trending overturned section with northwest-trending overturned section (Kelley and Silver, 1952); direct continuation of wrench fault in Socorro area (Chapin, 1983).
2) Mud Springs Mts.:	N 10 W strike-slip structure; positive flower structure; en enchelon folds; R' folds; perpendicular normal faults; juxtaposition across strike-slip fault of complete Paleozoic section and incomplete Paleozoic section (Maxwell and Oakman, 1986a); associated 41 ma rhyolite dike (Maxwell and Oakman, 1986b).
3) Sierra Cuchillo-Animas Uplift:	R' shears and thrusts; horizontally striated slickensides; remnants of positive flower structure; northward, decreasing ages of intrusive rocks.
4) Chloride area:	Zone of anastomosing strike-slip faults, R shears, and R' shears (Harrison, 1989); offset of exotic blocks (this paper).
5) Santa Rita-Hanover axis:	Narrow (1.5-3.0 km), elongated (>55 km), north-northeast-trending, early Tertiary structural and topographic high (Elston et al., 1970; Aldrich, 1972, 1974, 1976); horizontally striated slickensides and mullions (Jones et al., 1967); forcibly emplaced intrusions (Aldrich, 1972, 1974).

Re-activation of some of these structures, during younger tectonism related to the Rio Grande rift, has greatly clouded and obscured their wrench-fault heritage, to the point that only R′ shears, subsidiary faults and folds and remnants of the wrench faults remain. Other wrench-faults, such as those that cut exotic blocks in the Chloride area of the Black Range and the structure found in the Mud Springs Mountains, are better preserved and more easily identified.

Santa Rita–Hanover axis

My hypothesis proposes that the Santa Rita–Hanover axis is basically a wrench-fault structure; part of the wide zone described above. It is envisioned that a "pop up" structure or compressional uplifted block, similar to those described by Reading (1980), Sylvester and Smith (1976) and Sylvester (1988) produced a local escarpment from which large pieces of Pennsylvanian section detached and slid under the force of gravity toward the northeast. A small limestone outcrop, with all the characteristics of the Pennsylvanian section near Santa Rita, occurs on top of an early Tertiary topographic high along the Santa Rita–Hanover axis (Aldrich, 1976; Ratté et al., 1979). This outcrop is approximately 38 km southwest of exotic block occurrences, possesses clastic/limestone and sandstone/shale ratios similar to the blocks and perhaps marks their general detachment area.

The Santa Rita–Hanover axis has many characteristics of a wrench-fault ancestry. It is a narrow (1.5–3.0 km), north-northeast-trending structural feature at least 55 km long (Aldrich, 1976), with possible buried, northward extension suggested by gravity data (Cordell et al., 1982), paleo-topographic highs involving the Rubio Peak Formation (Richter et al., 1986) and orientation and alignments of Taylor Creek Rhyolite intrusives (Duffield et al., 1987; Eggleston, 1987). This narrow axis is interpreted as having been a structural and topographic high feature during Late Cretaceous, early Tertiary and mid-Tertiary time (Elston et al., 1970; Aldrich, 1972); and as having controlled plutonism by "forceful injection" over a period of at least 15 million years beginning in the late Paleocene (Aldrich, 1972, 1974, 1976). Jones et al. (1967) report horizontal slickenside striations and mullions on some of the faults along the Santa Rita–Hanover axis, in mines of the Santa Rita area.

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