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Proterozoic plutonism and regional deformation—new constraints from the southern Manzano Mountains, central New Mexico

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Abstract

The relative importance of Early Proterozoic versus Middle Proterozoic deformation and metamorphism in the southwestern U.S. is currently a topic of debate. The Manzano Mountains of central New Mexico are an ideal testing ground for evaluating the principal opposing models of Proterozoic orogenesis. The range contains well-exposed granitoids of Early and Middle Proterozoic age and diverse deformational character, porphyroblast microstructures, and major structures such as refolded folds, regional mylonitic foliations, and ductile shear zones.

The dominant, northeast-striking, subvertical foliation (S_2) and associated upright folds (F_2) represent regional shortening (D_2) after crystallization of the 1656 Ma Monte Largo pluton. Greenschist-grade S_2 is particularly well developed along the pluton margins. In contrast, the 1427 Ma Priest pluton crosscuts F_2 folds and is largely nonfoliated. Regional northwest–southeast shortening is therefore bracketed between 1656 Ma and 1427 Ma, consistent with the chronology of deformation established from other plutonic rocks in New Mexico and southern Colorado. In general, 1690–1650 Ma plutons are moderately to highly deformed, whereas 1450–1350 Ma plutons are weakly deformed to undeformed. The distribution and kinematic significance of 1.4 Ga and post-1.4 Ga deformations remain controversial, but regional data suggest that Middle Proterozoic events were superposed on Early Proterozoic metamorphic terranes that record the northwest–southeast convergent assembly of the southwestern U.S.

Introduction

The timing of Proterozoic orogenic events in New Mexico is controversial. U–Pb zircon data indicate that volcanogenic sequences and granodioritic plutons record crustal accretion in the interval 1750–1650 Ma. One view is that an important phase of deformation and metamorphism was associated with assembly of crustal terranes during this 100 m.y. orogenic interval; this phase was followed by relative tectonic quiescence that was interrupted by magmatic events at ca. 1.4–1.1 Ga (Bowring and Karlstrom, 1990; Karlstrom and Bowring, 1991; Bowring, 1991; Bauer et al., 1991; Bauer et al., 1992; Shastri and Bowring, 1992; Bauer and Williams, in press). An alternate view is that the regional structures and tectonic foliation and the regional amphibolite-grade metamorphic assemblages formed during a complex interplay of contractional and extensional deformation at ca. 1.4 Ga and later (Grambling et al., 1989; Thompson et al., 1991; Grambling and Dallmeyer, in press; Daniel et al., 1992).

Timing of deformation in New Mexico comes principally from two sources, U–Pb and $^{40}Ar/^{39}Ar$ geochronology. U–Pb zircon ages on granitoids can constrain deformational and metamorphic histories of orogenic belts if the relative timing of deformation, metamorphism, and plutonism is established by detailed field and microstructural work (e.g. Paterson and Tobisch, 1988). The mountains of New Mexico contain dozens of Proterozoic granitoids that range in composition, emplacement age, nature and degree of deformation, and field relationship to country rock. Condie and Budding (1979) listed 31 Proterozoic plutons in central and south-central New Mexico alone. To date, U–Pb zircon isotopic ages based on concordia diagrams have been published for only nine of these plutons (Bauer and Pollock, 1993). Of these, six have either large uncertainties or are presented without data in abstracts or as personal communications, and only a limited number have had detailed field and structural studies. Nevertheless, most workers have noted that plutons older than about 1650 Ma are strongly deformed and that plutons of ca. 1450 Ma are only weakly deformed or nondeformed (Williams, 1990; Bauer et al., 1991; Bauer, 1993; Bauer and Williams, in press). This generalization is supported by recent work in the Magdalena Mountains of central New Mexico, where Bauer et al. (1991) and Bauer and Williams (in press) showed that regional tectonism took place at 1660 Ma by comparing precisely dated deformed and undeformed Early Proterozoic igneous rocks. Similarly, Karlstrom and Bowring (1988, 1991, 1993) documented a 90 m.y. interval (1740–1650 Ma) during which deformation took place in Arizona, including a pulse at ca. 1650 Ma in southern Arizona, termed the Mazatzal orogeny.

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Also in this issue

Sulfide/barite/fluorite mineral deposits, Guadalupe Mountains p. 56
Middle Jurassic Summerville Formation p. 66
NMGS 1993 spring meeting abstracts p. 71
Upcoming geologic meetings p. 78
Geographic names p. 78
Service/News p. 79
Staff notes p. 80

Coming soon

Oil and gas discovery wells drilled in 1992

Geochronology of Mt. Taylor, Cebollita Mesa, Zuñi–Bandera volcanic fields

Evidence for major deformational and metamorphic events at 1.4–1.0 Ga comes from $^{40}Ar/^{39}Ar$ dating of metamorphic minerals and study of the contact aureoles of ca. 1450 Ma plutons. Recent studies have shown that $^{40}Ar/^{39}Ar$ hornblende ages in New Mexico are generally in the range of 1450–1350 Ma (Grambling and Dallmeyer, 1990; Thompson et al., 1991; Grambling and Dallmeyer, in press). Because peak regional metamorphism was near 550°–600°C, hornblende ages have been interpreted to record cooling through 500°–550°C, shortly following peak regional metamorphism and deformation. These workers suggested that apparent differences in degree of deformation of 1.65 Ga and 1.4 Ga plutons reflect partitioning of strain around the young plutons rather than different deformational histories. Muscovite ages are substantially younger (1350–1000 Ma) and were interpreted to reflect reheating of crustal blocks to around 350°C during discrete Middle Proterozoic events. Muscovite ages that differ across major ductile faults were interpreted to record late juxtapositions (Thompson et al., 1991; Grambling et al., 1992). Alternatively, Bowring and Karlstrom (1990) interpreted the young $^{40}Ar/^{39}Ar$ data as cooling ages related to 1450 Ma and 1100 Ma magmatic events and associated differential uplift of crustal blocks long after Early Proterozoic regional deformation and metamorphism.

In this paper we present new U–Pb zircon isotopic data for two granitoids in the southern Manzano Mountains and briefly describe their structural/metamorphic settings. The new data provide a chronologic background for ongoing and much-needed future detailed structural and petrologic work on these plutons. The Manzano Mountains may turn out to be a key locale for reconciling the two competing orogenic models because of the combination of well-exposed granitoids of Early and Middle Proterozoic age and diverse deformational character, porphyroblast microstructures, and major structures such as refolded folds, regional mylonitic foliations, and ductile shear zones. Our current view is that existing data are best explained by a model in which Early Proterozoic tectonic and metamorphic fabrics were variably affected by multiple Middle Proterozoic events.

Geology of the Manzano Mountains

Both the Monte Largo and Priest plutons were originally named and described by Stark (1956) in his excellent field study of Precambrian rocks of the southern Manzano Mountains. Subsequent work includes: 1) Myers and McKay (1972, 1974)—generalized geologic maps of the southern Manzano Mountains; 2) Bolton (1976)—Rb–Sr geochronology of the Priest pluton; 3) Myers (1977)—map of the southern part of the Priest pluton; 4) Condie and Budding (1979)—a study of Precambrian rocks of central New Mexico, including geochemistry of the Monte Largo and Priest plutons; 5) Maxwell and Wobus (1982)—a map of the Manzano Wilderness study area; 6) Bauer (1982, 1983a, 1983b)—map and structural analysis of the southern Manzano Mountains; and 7) Thompson et al. (1991)—metamorphic petrology and $^{40}Ar/^{39}Ar$ thermochronology of parts of the southern Manzano Mountains.

The Monte Largo pluton (Monte Large granite of Stark, 1956) intrudes metasedimentary rocks on the western flank of the range, between West Bartolo Canyon and Monte Largo Canyon (Fig. 1). The Priest pluton (Priest granite of Stark, 1956) is exposed 5 km (3.1 mi) to the south, along the Laramide-age(?) Montosa fault (Fig. 1). Separating the two plutons is a steeply dipping, northeast-striking succession of amphibolite, mafic schist, quartzofeldspathic schist, pelitic schist and phyllite, muscovite quartzite, and crossbedded quartzite (Stark, 1956; Bauer, 1983b). Bowring et al. (1983) reported a U–Pb zircon age of about 1680 Ma for a metarhyolite northeast of the Monte Largo pluton. Bauer (1983a) concluded that a simple stratigraphic sequence does not exist in the southern Manzano Mountains. Instead, supracrustal rocks have been complexly deformed by at least three deformational events and are stacked along layer-parallel (now subvertical), ductile thrusts. The predominant structures in the range are tight to isoclinal, gently to moderately plunging, upright, second-generation folds (F_2) that fold a layer-parallel schistosity (S_1) and rare associated isoclinal folds (F_1). F_2 sheath folds have been found in the southern Manzano Mountains (S. Ralser, pers. comm. 1993). Sets of broad folds (F_3) and crenulation cleavages (S_3) crosscut F_2 folds. Bauer (1982) reported that regional metamorphism accompanied the D_1 and D_2 deformations and that the posttectonic Priest pluton displays a sillimanite-grade, contact-metamorphic aureole.

Monte Largo pluton

The Monte Largo pluton is located on the western flank of the range at the junction of the Tome NE, Tome SE, Capilla Peak, and Manzano Peak 7½-min quadrangles (Fig. 2). Variably deformed granodiorite, quartz monzonite, and granitic rock are exposed over an area of about 4 km^2 (1.5 mi^2) that is bounded on three sides by strongly deformed quartzite and phyllite (Blue Springs schist of Stark, 1956). The granodiorite is medium grained and consists mainly of altered feldspar (30–40%, much is now sericite), quartz (20–25%), chloritized biotite, rare hornblende (altered to chlorite and biotite), and epidote. Minor phases include calcite, apatite, zircon, tourmaline, and altered sphene. Mafic enclaves are common in the granodiorite; pegmatites are rare. Stark (1956) reported apophyses of granitic rock within phyllite, and recent mapping identified quartzite blocks surrounded by granite, all tectonized but apparently in an intrusive contact. Condie and Budding (1979) noted that major and trace-element concentrations in the Monte Largo pluton resemble those in the Ojita pluton of the northern Manzano Mountains (Fig. 1). To date, the Ojita pluton has been neither mapped nor isotopically dated.

Country rocks were originally designated "Blue Springs schist" by Stark (1956). This unit includes a number of distinctive and mappable rock types (Fig. 2). Quartzite horizons contain crossbedding and distinctive, banded hematite-rich zones, indi-

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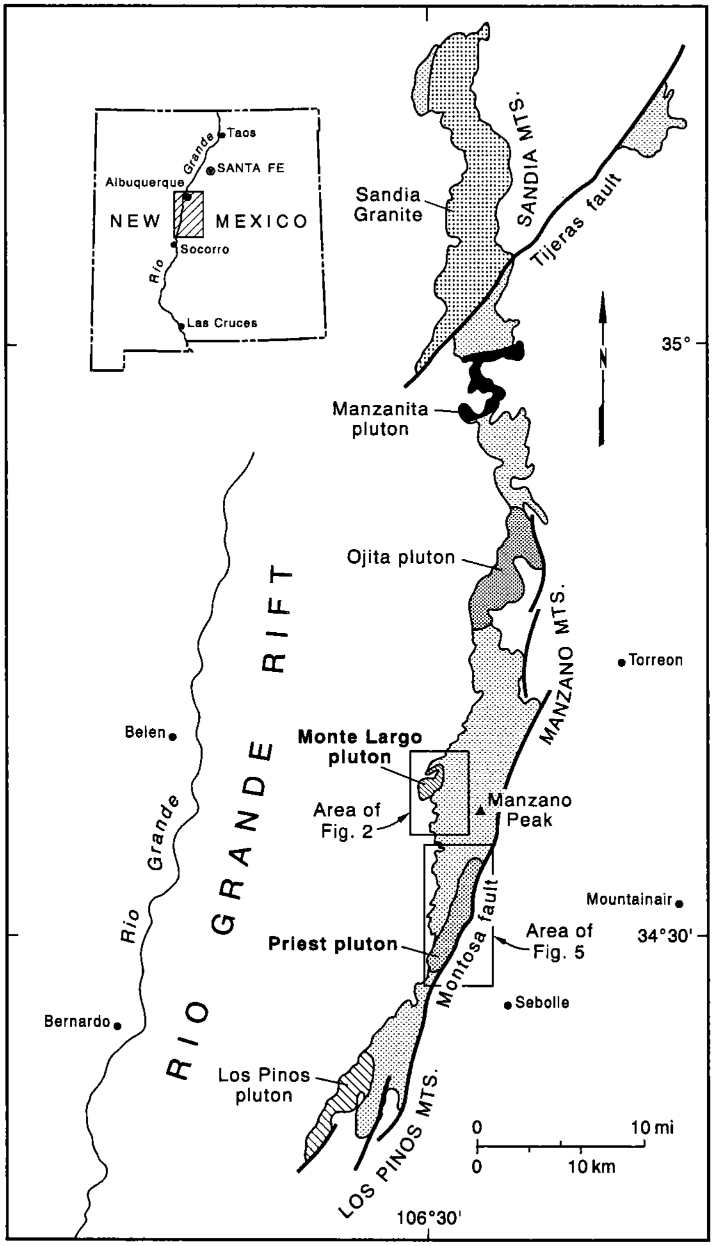

FIGURE 1—Location of major Proterozoic granitoids in the Manzano and Sandia Mountains, central New Mexico.

cating that they represent metasedimentary layers (in agreement with Grambling, 1982), rather than intrusive vein quartz "reefs" (Stark, 1956). Quartzite forms a boudinaged but semicontinuous layer adjacent to the Monte Largo pluton, and similar quartzites are present in pods within the surrounding schists (Fig. 2). Because they are similar in appearance and because there is evidence for mesoscopic isoclinal folds (Fig. 2), we interpret the quartzites to be the same unit or similar units, strongly attenuated and structurally transposed and repeated by F_1 and F_2 folds and thrusts. Similarly, metarhyolite layers are tectonically stacked and interlayered with schist and quartzite. The main compositional layering (S_1) and associated banding and interlayering of repeated quartzite–schist–metarhyolite units are folded about a map-scale, asymmetric F_2 fold that is cored by the Monte Largo pluton (Fig. 2).

The Monte Largo pluton is variably foliated, and deformational fabrics in the pluton can be correlated with fabrics in the country rocks (Fig. 3). Foliation is especially intense along the pluton margin, where the granite is mylonitic, showing top-to-the-west shearing (Fig. 4). This fabric is parallel to S_1 in the country rock, and both are folded by the large F_2 antiform, suggesting that pluton and country rock were deformed together during northwest-directed F_1 shearing and isoclinal folding. This folding represents continued attenuation of the S_1 tectonite layering on F_2 fold limbs. Late, low-angle, top-to-the-northwest shear bands (S_3) in the schist may represent a discrete, low-temperature event superposed on F_1/F_2 or a continuation of the top-to-the-west contraction. The pluton locally contains an S_2 crenulation cleavage that is axial planar to the large F_2 antiform. Such structures indicate that thrusting and shortening postdated pluton crystallization.

The S_1 cleavage developed at approximately greenschist grade, as shown by pervasive, syndeformational reaction softening of plagioclase to sericite and quartz and retrogression of biotite in the pluton to chlorite. The relative persistence of quartz phenocrysts is compatible with the observation that quartz can be stronger than reaction-softened feldspars at greenschist and amphibolite grades (Williams and Burr, in press). Adjacent pelitic schist also contains greenschist-grade assemblages of chlorite, quartz, muscovite, and actinolite. The absence of a contact-metamorphic aureole around the pluton suggests shallow emplacement and/or elimination of contact-metamorphic features by postpluton, retrograde greenschist-grade deformation. Abundant pegmatites in the metarhyolite, which have been folded, boudinaged, and disconnected like tectonized pods of partial melt, suggest the possibility that earlier, high-temperature metamorphism and deformation (pre-S_1 in granite) did affect country rocks (in agreement with Shastri, 1993, in Los Pinos Mountains).

Priest pluton

In striking contrast to the predeformational (pre-S_2) Monte Largo pluton, deformational and metamorphic fabrics around the Priest pluton record events that were superposed on the D_1 and D_2 fabrics described above. The Priest pluton is a 10-km-long (6-mi-long), north-trending, elongate intrusion that lies within the Manzano Peak and Scholle 7½-min quadrangles (Fig. 1). The pluton is bounded on the east by the Phanerozoic Montosa fault, but intrusive contacts with quartzite and schist are exposed on the other three sides (Fig. 5). The main mass of the pluton is composed of approximately 60% feldspar, 30% quartz, and 5% biotite (commonly altered to chlorite and epidote) plus epidote, magnetite, apatite, hematite, zircon, and allanite. Light-pink microcline megacrysts are euhedral, up to 8 cm long, and commonly aligned in a magmatic foliation. Pegmatites, enclaves, and epidote veins are common. The Priest pluton is similar in composition (Condie and Budding, 1979) and Rb–Sr isochron age (Brookins, 1982) to the Sandia pluton and other ca. 1450 Ma granites and quartz monzonites of central New Mexico.

Although deformational fabrics in country rock around the Priest pluton are similar to those around the Monte Largo pluton, fabrics in the Priest pluton itself are much less intense than in the adjacent country rocks, and the pluton cuts map-scale F_2 folds along the northern contact (Bauer, 1983a; Fig. 5). These relationships suggest that most of the regional deformation predated pluton emplacement. In the country rocks the earliest foliation (S_1) is a schistosity that is typically subparallel to bedding in quartzites. S_1 is folded by upright, shallowly plunging F_2 folds that have a subvertical, axial-plane crenulation cleavage (S_2) that is especially well developed in schistose units. Shear-sense indicators in mylonitic quartzites show west-side-up shearing on S_2 (Goodwin et al., 1992; Fig. 6A), consistent with asymmetric folds mapped by Bauer (1983b). In these mylonites, quartz grains typically exhibit straight to moderately curved boundaries and low aspect ratios; undulatory extinction is uncommon. These features are compatible with deformation during amphibolite facies conditions (cf. Simpson, 1985; Goodwin et al., 1992), which is consistent with mineral assemblages in adjacent pelitic schists (Thompson and Karlstrom, 1993). Along the western pluton margin, the F_2 enveloping surface of folded S_1 tectonite layering is truncated by the subvertical pluton margin. Because F_1/F_2 structures here are

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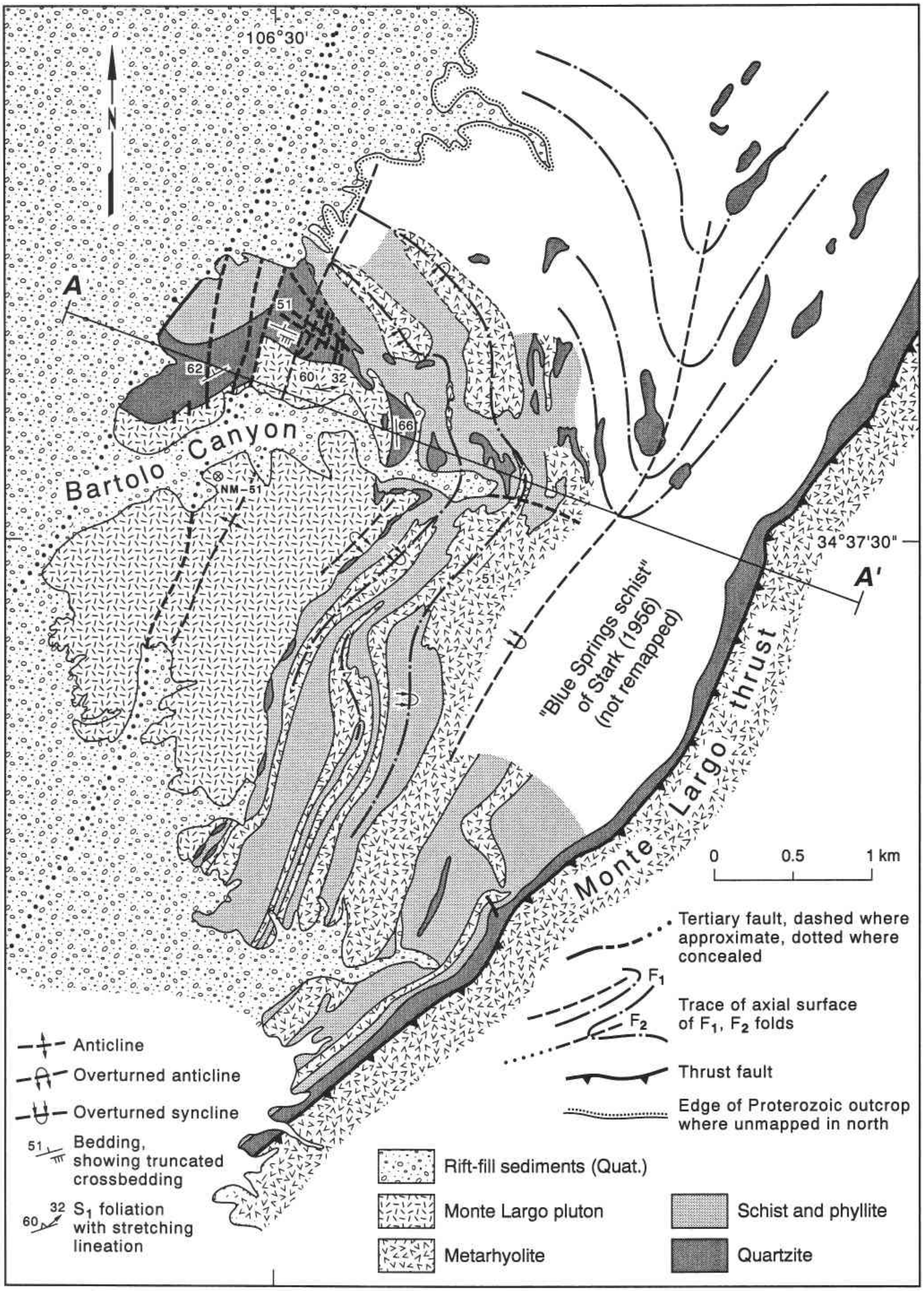
106°30'
N
A
A'
34°37'30"
51
62
60
32
66
NM-51
51
Bartolo Canyon
"Blue Springs schist" of Stark (1956) (not remapped)
Monte Largo thrust
0
0.5
1 km
Tertiary fault, dashed where approximate, dotted where concealed
F1
F2
Trace of axial surface of F1, F2 folds
Thrust fault
Edge of Proterozoic outcrop where unmapped in north
Anticline
Overturned anticline
Overturned syncline
51
Bedding, showing truncated crossbedding
32
60
S1 foliation with stretching lineation
Rift-fill sediments (Quat.)
Monte Largo pluton
Metarhyolite
Schist and phyllite
Quartzite

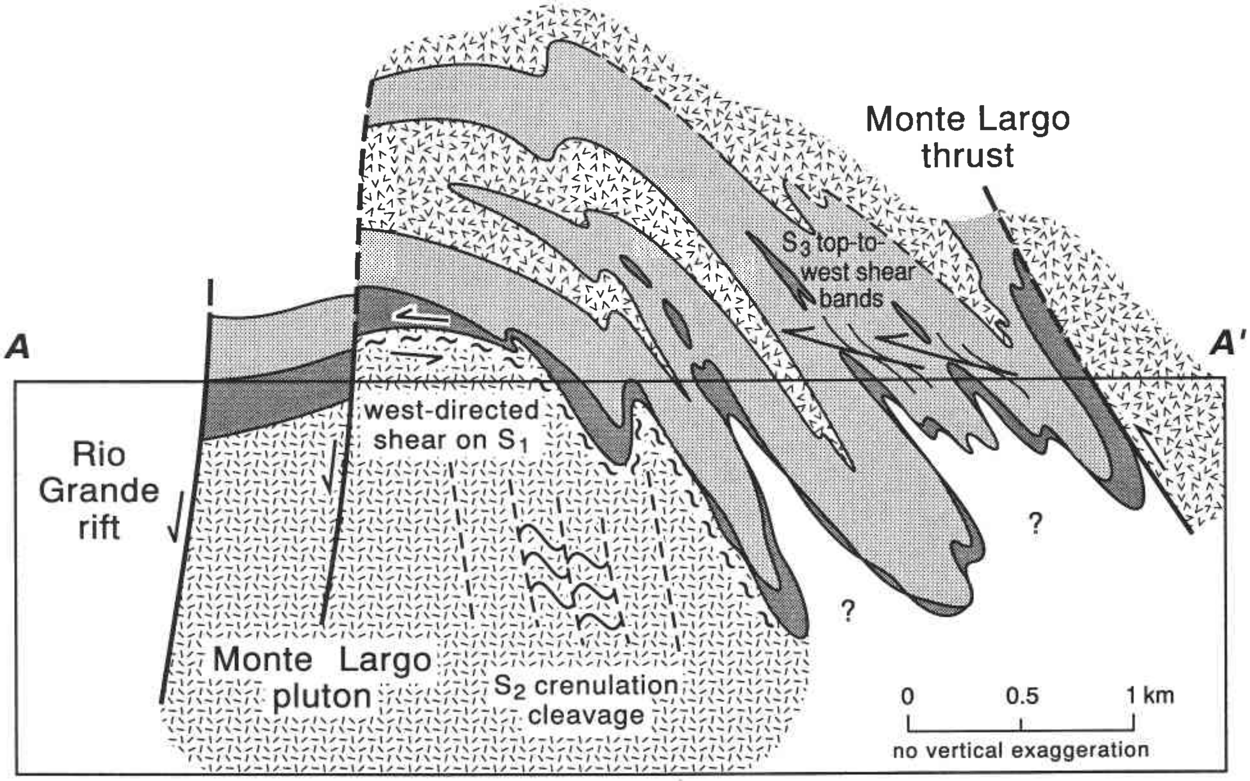

FIGURE 2—Generalized geologic map and schematic cross section of the Monte Largo pluton and surrounding country rock. The shear bands and S_2 crenulation cleavages are not shown to scale. NM–51 is location of geochronology sample. Based on unpublished mapping by K. E. Karlstrom et al. (1992).

FIGURE 3—Photomicrograph of F_2 folds and associated S_2 axial-plane cleavage overprinting S_1 in metarhyolite east of Monte Largo pluton. Cross-polarized light. Field of view is 3 mm. Sample no. BC–92–5.

FIGURE 4—Photomicrograph of S_3 shear bands in Monte Largo pluton showing top-to-the-northwest (top-to-the-right) movement. S_1 is folded by F_2 folds and S_2 deflected into shear bands. From eastern contact with quartzite. White mineral is quartz; plagioclase has been replaced by mica. Plane polarized light. Field of view is 12 mm. Sample no. BC–421.

similar in style and orientation to those near the Monte Largo pluton, we correlate them and thus conclude that their development is restricted to the time interval that separates crystallization of the two plutons.

The Priest pluton contains a variably developed, broadly greenschist-grade, mylonitic foliation (S_3) that is northeast-striking and generally parallel to S_2 in the country rock. S_3 is the only ductile tectonite fabric found in the Priest pluton. This fabric is most intense along the pluton margin and in pegmatite and aplite dikes near the margin. In the pluton, S- and C-surfaces record east-side-up shear (Fig. 6B). In contrast with S_2, S_3 is associated with features that suggest deformation during greenschist facies conditions (Goodwin et al., 1992). Strongly elongate, undulose, quartz ribbons, having subgrain development along grain margins, are common. Feldspar grains are typically fractured. S_3 formation therefore must have postdated the locally high temperatures (700°C or more) associated with pluton emplacement. We correlate this S_3 with S_3 near the Monte Largo pluton because of its low-temperature character and similar shear sense.

Amphibolite-grade metamorphic isograds are parallel to the western and northern margins of the Priest pluton, suggestive of a contact aureole (Grambling et al., 1992). Isograds crosscut

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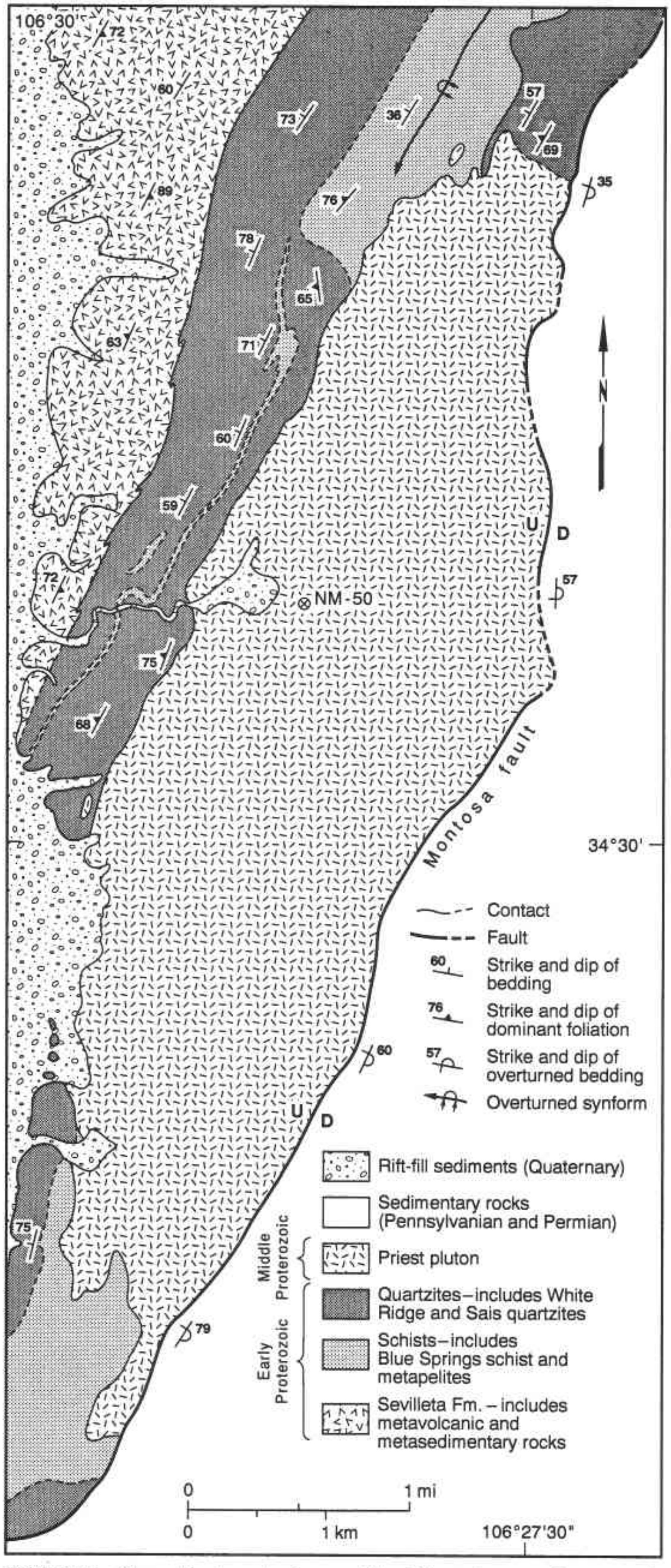

FIGURE 5—Generalized geologic map of the Priest pluton and surrounding country rock. NM–50 is location of geochronology sample. Modified in part from Bauer (1983b), Stark (1956), and Myers (1977).

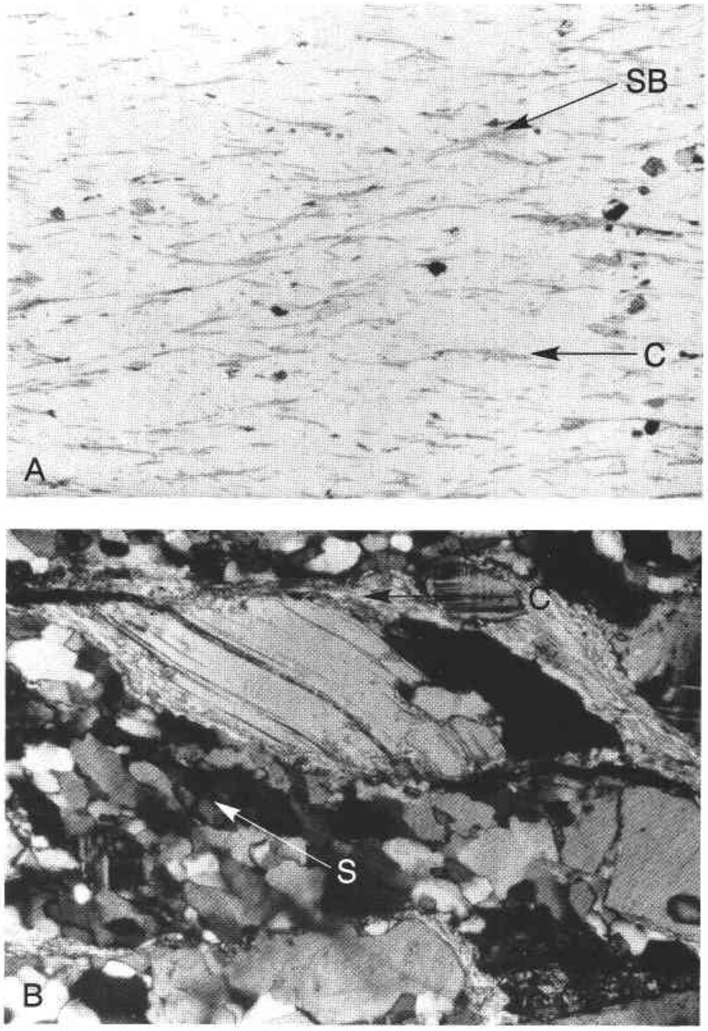

FIGURE 6—Microstructures from Estadio Canyon along the west margin of the Priest pluton. **A**, photomicrograph of mylonitic quartzite; C-surfaces (C) and shear bands (SB) indicate a west-side-up shear sense on S_2. Sample no. E–7a. Field of view is 6.5 mm. **B**, photomicrograph of S- and C-surfaces in Priest pluton indicating east side up on S_3. Sample no. E–3. Field of view is 1.3 mm.

the major F_1/F_2 country-rock structures, supporting the interpretation that pluton crystallization postdated most of the regional deformation. Porphyroblast–matrix relationships indicate growth of metamorphic minerals before, during, and after S_2 (Thompson and Karlstrom, 1993), suggesting a complex overprinting of contact metamorphism on earlier regional metamorphic assemblages and reactivation of old (S_1/S_2) foliations during and after pluton emplacement.

Geochronology

Before this study, no isotopic ages existed for the Monte Largo pluton, and the only constraint on the Priest pluton was an Rb–Sr isochron age of 1470 ± 30 Ma (Bolton, 1976). In New Mexico Rb–Sr isochrons commonly yield ages that are significantly younger than U–Pb zircon ages (Bauer and Pollock, 1993).

A 50 lb sample of the Monte Largo pluton was collected for U–Pb zircon geochronology from the location shown in Fig. 2 as NM–51 (UTM coordinates 3832700mN, 362500mE). In thin section the sample consists of rounded and elongated quartz megacrysts in an altered matrix of fine-grained white mica, chlorite, and quartz. Quartz megacrysts average about 3 mm in diameter and are composed of a mosaic of subgrains that show strong undulose extinction. Feldspars have been completely replaced by mica, chlorite, and quartz. The fine-grained, foliated micaceous matrix wraps around quartz grains. Minor phases include Fe-oxide minerals and zircon. The sample was crushed, sieved (<100 mesh), and concentrated at the New Mexico Bureau of Mines and Mineral Resources. The mineral concentrate contained abundant euhedral zircon. A three point concordia diagram yields an upper intercept age of 1656 ± 10 Ma for the Monte Largo pluton (Fig. 7).

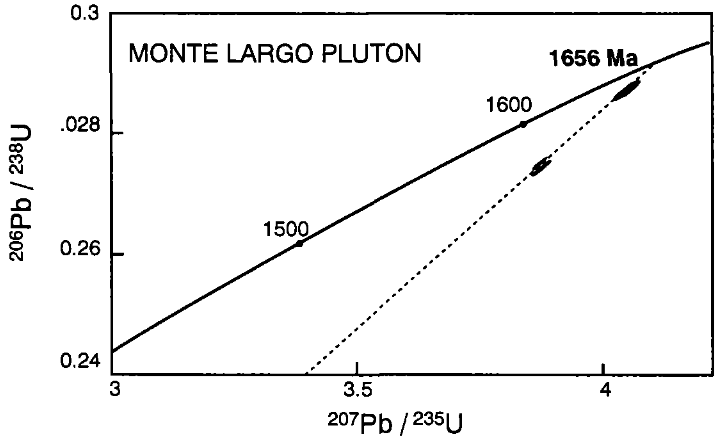

FIGURE 7—Preliminary concordia diagram for the Monte Largo pluton.

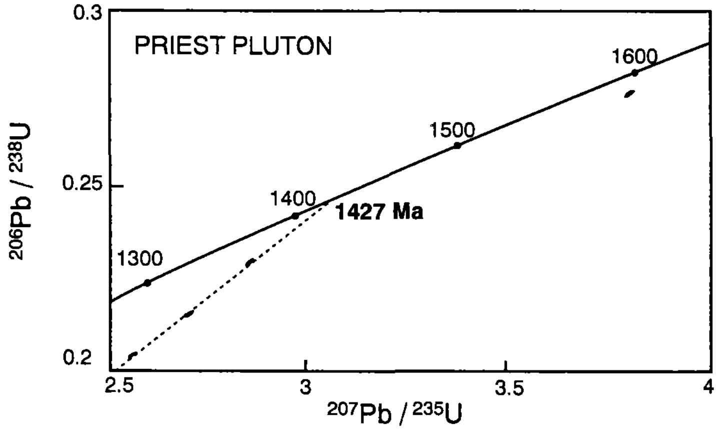

FIGURE 8—Preliminary concordia diagram for the Priest pluton.

A 50 lb sample of the Priest pluton was collected for U–Pb zircon geochronology from the location shown in Fig. 5 as NM-50 (UTM coordinates 3820000mN, 364000mE). In thin section the pluton consists of about 60% feldspar, including euhedral grains of slightly altered microcline (20 mm), and scattered grains of albite altered to white mica, epidote, and quartz. Quartz consists of irregularly shaped grains that range from 0.1 mm to 10 mm in diameter. Biotite is typically altered to chlorite and epidote. Minor phases of magnetite, apatite, hematite, zircon, and allanite are scattered throughout. The sample was crushed, sieved (<100 mesh), and concentrated at the New Mexico Bureau of Mines and Mineral Resources. The heavy-mineral concentrate contained abundant euhedral zircon. A three point concordia diagram yields an upper intercept age of 1427±10 Ma for the Priest pluton (Fig. 8). A fourth point that is nearly concordant at ca. 1600 Ma is probably an inherited component.

Discussion

The major folding (F_2) and foliation (S_2) in and around the 1656 Ma Monte Largo pluton represent regional shortening (D_2) after crystallization of the 1656 Ma Monte Largo pluton. In contrast, the 1427 Ma Priest pluton crosscuts F_2 folds and is largely nonfoliated. Regional northwest–southeast shortening is therefore bracketed between 1656 Ma and 1427 Ma, consistent with the chronology of deformation established from other plutonic rocks in New Mexico. With one exception, plutons in New Mexico with ages in the range of 1650–1690 Ma are moderately to highly deformed, whereas the ca. 1450 Ma plutons are undeformed to weakly deformed.

The exception is the undeformed Magdalena granite, which has a U–Pb zircon age of 1654±1 Ma (Bowring et al., 1983). Because nearby, highly strained metavolcanic rocks yielded a U–Pb isotopic age of 1664±3 Ma (Bowring et al., 1983), regional deformation was constrained at ca. 1660 Ma (Bauer et al., 1991; Bauer and Williams, in press). This conclusion is consistent with our inference that the ca. 1656 Ma Monte Largo pluton was emplaced before D_2 regional northwest–southeast shortening, whereas the 1427 Ma Priest pluton crystallized after D_2 shortening.

Regional D_2 deformation was accompanied by greenschist- to amphibolite-grade metamorphism and resulted in west-side-up shearing. In contrast, post-1427 Ma D_3 deformation took place at greenschist-grade conditions and resulted in east-side-up shearing in the Monte Largo pluton and along the Priest pluton margin. It remains unclear how, or if, the prepluton and postpluton deformations were related. If D_3 deformation was part of a progressive regional shortening, then deformation had greatly waned during Priest pluton emplacement, and structural vergence had reversed during post-1427 Ma convergence. Alternatively, D_3 strain could have been related to post-1427 Ma convergent tectonism and thermal events related to the Grenville (or pre-Grenville) orogeny. The latter idea is supported by ^{40}Ar/^{39}Ar muscovite cooling ages of 1300 Ma and younger from central and northern New Mexico (J. A. Grambling, pers. comm. 1992), which are compatible with new data indicating 1.3–1.2 Ga deformation in the Llano uplift of Texas (Walker, 1992).

Thus, available data seem best interpreted by a tectonic model that involved 1.66 Ga northwest–southeast shortening, long followed by 1.4 Ga pluton emplacement and then by additional shortening at ca. 1.3 Ga. The character of the 1.4 Ga event remains controversial. However, the recognition of a complex history of overprinting of Middle and Early Proterozoic thermal and deformational events is a first step toward evaluating the extent, thermal regimes, and kinematic history of 1.4 Ga deformation and metamorphism in the Southwest.

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(Continues on p. 77)

that we must seriously consider that the tracks may be allied to *Tetrasauropus*. If this interpretation is correct then this is also the first report for this ichnogenus in North America. It is accepted, at least by some ichnologists, that the Lower Jurassic ichnogenus *Otozoum* is attributable to a prosauropod and that it is similar to *Pseudotetrasauropus* and *Tetrasauropus*. Given that *Otozoum* and another prosauropod track *Navahopus* are both known in the Lower Jurassic of the western United States and that Late Triassic skeletal remains of at least one prosauropod are known, it is reasonable to infer that prosauropod tracks should occur at this time. The ichnogenera *Tetrasauropus* and *Pseudotetrasauropus* warrant further study to determine their distribution in western North America and to establish if they are of prosauropod affinity, as proposed by Ellenberger.

(*Continues in next issue*)

New Mexico Geological Society 1994 Fall Field Conference

Call for papers

The 1994 NMGS Fall Field Conference will tour the Mogollon Slope of west-central New Mexico from September 28 to October 1, 1994. The Mogollon Slope is generally defined by southerly dipping Tertiary volcanic and volcaniclastic strata that overlap the southern structural margin of the Colorado Plateau between Socorro, New Mexico and Springerville, Arizona. The conference will focus on the Cenozoic stratigraphic, structural, and topographic evolution of the Plateau margin. Additional topics will be recent wildcat oil-test wells in the Mangas Mountains area, ongoing development of an open-pit coal mine near Quemado by the Salt River Project, aspects of regional hydrologic studies, and seismic reflection profiles for the San Agustin Plains region. A four-wheel-drive caravan is planned to permit access to the scenic back country north and south of U.S. 60.

Scientific papers, technical review articles, and minipapers are being solicited for the conference guidebook. NMGS guidebooks typically cover a wide range of topics in geology, geophysics, geochemistry, economic geology, hydrology, archeology, engineering, and regional history. If you plan to submit an article or minipaper for the guidebook, please send a tentative title, estimate of manuscript length, and information concerning figures and tables to: NMGS-1994 FFC, Richard M. Chamberlin, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801, prior to **January 7, 1994.** Also, be sure to request "Instructions to Authors" before you start writing. All articles and road log contributions for the Mogollon Slope guidebook must be submitted by **February 15, 1994.** Managing editor for the guidebook will be Barry Kues, and technical editors will be Richard Chamberlin, Jim Barker, and Bill McIntosh. For additional information, contact Richard Chamberlin (505-835-5310/5420; fax (505-835-6333).

Bauer et al.

(*Continued from p. 55*)

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