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GEOLOGY AND U-Pb GEOCHRONOLOGY OF PROTEROZOIC ROCKS IN THE VICINITY OF SOCORRO NEW MEXICO

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INTRODUCTION

The purpose of this report is to summarize the results of reconnaissance mapping and U-Pb geochronology for the major exposures of Proterozoic rocks in the vicinity of Socorro, New Mexico. The areas of Proterozoic outcrop discussed here are shown in Figure 1 and include the Lemitar, Magdalena, and Chupadera Mountains. U-Pb zircon ages are reported for three granites and two felsic metavolcanic units in these areas.

Published geologic reports concerning Proterozoic rocks of the Magdalena (Condie and Budding, 1979; Sumner, 1980; Loughlin and Koschmann, 1942) and Lemitar (Condie and Budding, 1979; McLemore, 1980) Mountains have implied simple stratigraphic successions upon which tectonic models have been based. Recent work on Proterozoic rocks of the Pedernal Hills (Armstrong and Holcombe, 1982) and the Manzano (Grambling, 1982; Bauer, 1982, 1983) and southern Sangre de Cristo (Grambling and Codding, 1982) Mountains have documented complex structural histories involving multiple episodes of deformation. In light of these studies, we have re-examined the outcrops of Proterozoic rocks in the Socorro area to evaluate this apparent difference in structural style and to establish a chronologic framework of magmatism to compare with other areas of central New Mexico.

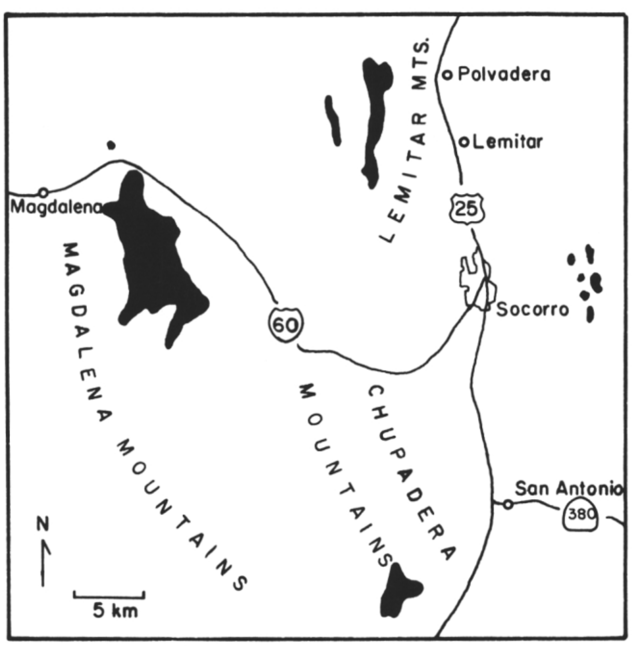

Figure 1. Map showing areas of Proterozoic outcrop in the Socorro area.

In the three major outcrop areas discussed here, geologic mapping has been primarily lithologic; detailed structural analysis has not yet been attempted. However, it is important that in all areas of Proterozoic rocks discussed in this report, structural complexity precludes any discussion of stratigraphy or apparent thicknesses of units at this time and we limit ourselves to discussing general lithologies and preliminary structural observations.

U-Pb analyses were done at the University of Kansas using an automated 22.5 cm radius, single-filament mass spectrometer. Zircon analyses (Table 1) followed the general method of Krogh and Davis (1973). Analytical blanks range from 0.6 to 1.2 nanograms total Pb. Corrections for non-radiogenic Pb were made using model Pb compositions of Stacey and Kramers (1975). All data reduction and age calculations were done using the constants recommended by Steiger and Jager (1977). Concordia intercept ages were derived using a York (1969) least-squares fit for the discordia lines and calculating the intercept ages from the mean slope and the -± 1 sigma slope. Uncertainties are reported at the one sigma uncertainty level.

MAGDALENA MOUNTAINS

The largest exposure of Precambrian rocks in the Socorro area is in the Magdalena Mountains, 40 km west of Socorro (figs. 1 and 2). Precambrian rocks crop out continuously along the eastern flank of the range from Water Canyon to the northern end of the range; small exposures occur north of U.S. 60 and in small blocks on the western side of the range. Approximately one-third of the exposure consists of interlayered metasedimentary and metavolcanic rocks. These rocks are intruded by and form large roof pendants in a gabbro pluton (gabbro of Garcia Canyon) and a large granite body (the Magdalena granite of Sumner, 1980).

The metasedimentary rocks are primarily quartz-sericite schists with minor amounts of quartzite, garnet-bearing quartzite, and biotite-garnet schist. They are generally fine grained, light greenish grey to light tan in color and are typically thinly layered. Minor amounts of coarse metasedimentary rock are present and contain cobble-sized clasts. Interlayered with the clastic metasedimentary rocks are porphyritic metarhyolites. These rocks contain phenocrysts of quartz, alkali feldspar, and plagioclase. A metarhyolite porphyry crops out near the summit of North Baldy (fig. 2) and has been interpreted as a dome complex (Sumner, 1980) that intrudes the metasedimentary rocks. The metarhy-

Table 1. Uranium and lead analyses and isotopic ratios for zircons from Proterozoic rocks in the Socorro area.

Sample Fraction[1]	Weight(m.y.)	Concentrations[2] U (ppm)	Pb (ppm)	Observed Pb Isotopic Ratios[3] 204/206	207/206	208/206	Calculated Isotopic Ratios[4] $^{206}Pb^*/^{238}U$	$^{207}Pb^*/^{235}U$	$^{207}Pb^*/^{206}Pb$
MAG-1									
A'	3.9	201	58	0.000471	0.10779	0.16211	0.2654	3.708	0.10132
A	6.2	193	59	0.001392	0.12047	0.19303	0.2639	3.689	0.10135
B	5.5	209	58	0.000769	0.11166	0.17457	0.2476	3.452	0.10110
C	6.1	295	70	0.000953	0.11364	0.18459	0.21142	2.931	0.10054
MAG-2									
C	1.1	348	95	0.000401	0.10721	0.15911	0.25361	3.556	0.10169
D	1.5	405	103	0.000378	0.10663	0.16224	0.23358	3.267	0.10143
EF	0.7	703	190	0.001371	0.12036	0.19504	0.23637	3.309	0.10153
Bulk	1.0	438	112	0.000713	0.11115	0.17463	0.23234	3.247	0.10135
MAG-3									
A[1]	2.4	261	76	0.000182	0.10423	0.17517	0.2678	3.756	0.10173
A	5.1	278	84	0.000198	0.10433	0.17830	0.2720	3.811	0.10161
B	10.3	284	86	0.000411	0.10748	0.18798	0.2703	3.795	0.10184
C	5.9	279	86	0.000885	0.11377	0.20383	0.2698	3.780	0.10162
S.82.304									
A	3.5	343	89	0.001145	0.11652	0.16637	0.2315	3.2165	0.10078
B	3.8	389	94	0.000943	0.11366	0.15162	0.2197	3.044	0.10049
C	4.3	445	97	0.000962	0.11341	0.14724	0.1984	2.741	0.10017
D	4.2	477	101	0.00178	0.12442	0.18128	0.1835	2.531	0.10000
S.82.305									
B	1.6	273	67	0.001732	0.12468	0.18752	0.2132	2.966	0.10087
C	2.7	349	78	0.001432	0.12015	0.17837	0.1970	2.729	0.10046
D	3.5	476	99	0.001920	0.12638	0.19636	0.1781	2.455	0.09997
E	2.8	605	116	0.001688	0.12300	0.16577	0.1658	2.281	0.09978

[1]Zircons were separated for analysis according to differing magnetic susceptibility: A'=least magnetic, F=most magnetic
[2]Corrected for blank
[3]Uncorrected for blank
[4]Corrected for blank, non-radiogenic Pb
*Radiogenic Pb

olite contains prominent quartz and alkali feldspar phenocrysts in a medium-grained groundmass.

The metasedimentary and metavolcanic rocks have been intruded by the gabbro of Garcia Canyon and a younger granite, the Magdalena granite (fig. 2). The gabbro of Garcia Canyon is medium grained and has well-developed ophitic texture. Typically, the gabbro contains 40—50 percent plagioclase, 3-4 percent clinopyroxene, and 40-50 percent hornblende which has replaced the clinopyroxene; accessory minerals include quartz, magnetite, biotite, and sphene. The Magdalena granite as defined by Sumner (1980) is a pink- to buff-colored, medium-grained rock that contains perthite, quartz, plagioclase, and biotite. The quartz and alkali feldspar are often graphically intergrown.

The metasedimentary rocks in the Magdalena Mountains show variable amounts of deformation. Although outcrops are poor and complicated by an abundance of Tertiary intrusives and faults, many of the metasedimentary rocks record several periods of deformation which have involved complete transposition of original lithologic layering. Much of what appears to be fine bedding in "siltstones and argillites" of Sumner (1980) is in fact a transposed layering; this is clearly illustrated in Figures 3 and 4. In outcrops just west of Strozzi Ranch (fig. 3), highly stretched pebbles form a prominent lineation parallel to the strike of layering; in some cases individual pebbles have been flattened to oblate and prolate ellipsoids. However, in other outcrop areas such as Copper Canyon (fig. 2) primary sedimentary structures are preserved and there is no evidence for transposed layering. The metarhyolite tuff that was sampled for geochronology has well-preserved vitroclastic texture. Thus, preliminary work suggests that intense deformation is domainal, localized in discrete zones which may be tectonic boundaries between different packages of rocks. The observations described above indicate that definitions of lithostratigraphic units and interpretations of depositional environments for the Proterozoic supracrustal rocks in the Magdalena Mountains must await detailed structural studies.

Three U-Pb zircon ages have been obtained from Proterozoic rocks in the Magdalena Mountains (fig. 3). The rhyolite of North Baldy and a felsic metatuff from the Shakespear Canyon area yield ages of approximately 1660 m.y. (fig. 5); the Magdalena granite yields an age of 1654 my. (fig. 6). Thus, reconnaissance geochronologic data indicates that the major Proterozoic magmatic activity in the Magdalena Mountains occurred over a time interval of at least 10 my.

The discordant nature of the contacts between the Magdalena granite and the supracrustal rocks, plus the lack of penetrative deformation in the granite, suggest that it was intruded after the major deformation and metamorphism in the Magdalena Mountains. Until a detailed structural analysis of the area is completed, this conclusion is regarded as tentative. However, if the Magdalena granite is post-tectonic, metamorphism and deformation in the Proterozoic of the Magdalena Range is tightly constrained to around 1655-1660 m.y.

The zircon data presented here differ from the Rb-Sr data of White (1977) who obtained two isochron ages for the Magdalena granite (1355± 139 m.y. and 1274 ± 63 my.) and an age of 1517 ± 239 my. for the gabbro of Garcia Canyon. The disturbance of Rb-Sr systems is also suggested in the Zuni Mountains where Brookins and others (1978) obtained ages of 1385 ±40 my. for metarhyolite and 1485 ±90 my. for granite gneiss, aplite, and granodiorite; Bowring and Condie (1982) report U-Pb zircon ages of 1650 my. for both metarhyolite and gneissic granite. Resetting of Rb-Sr isotopic systems in Precambrian rocks to produce colinear sets of data has been well documented by Page (1978), Bickford and Mose (1975), Van Schmus and others (1975), and Easton (1983). An important conclusion from these studies is that the reset

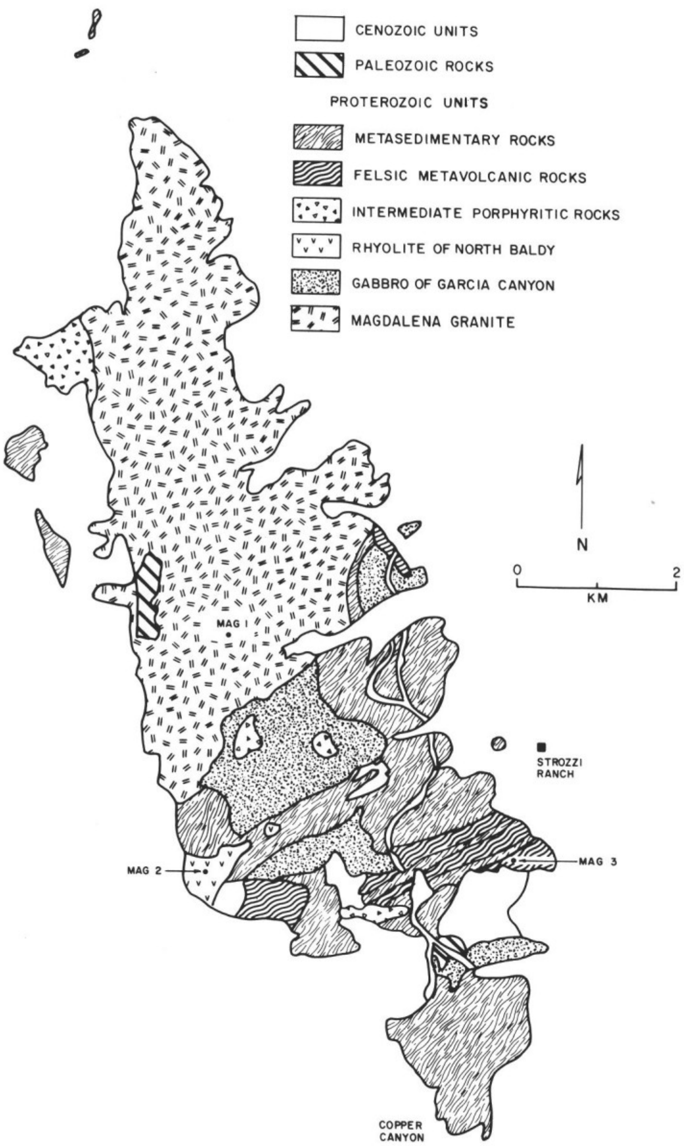

Figure 2. Generalized geologic map of the Magdalena Mountains (after Sumner, 1980). See Table 1 for analyses of samples indicated on map.

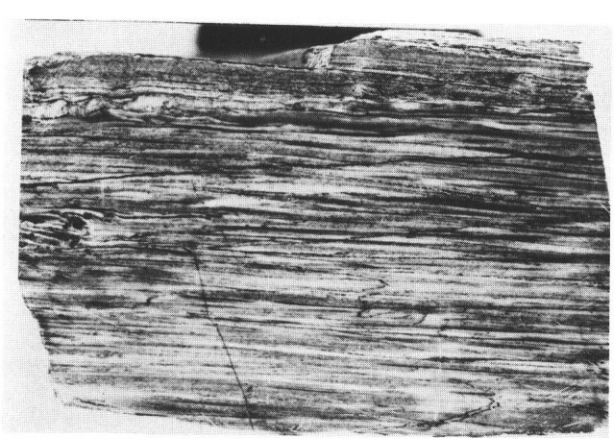

Figure 3. Highly discontinuous transposed layering in metasedimentary rocks west of Strozzi Ranch, Magdalena Mountains. Long dimension is 8 cm.

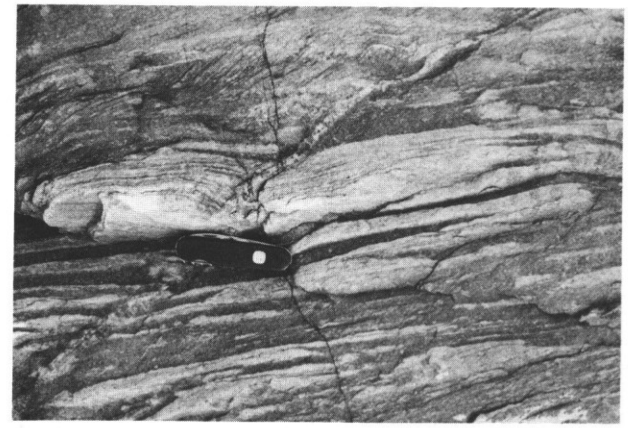

Figure 4. Transposed, fragmented, and lenticular layering in metasedimentary rocks from isolated outcrop north of U.S. 60. Knife is 10 cm long.

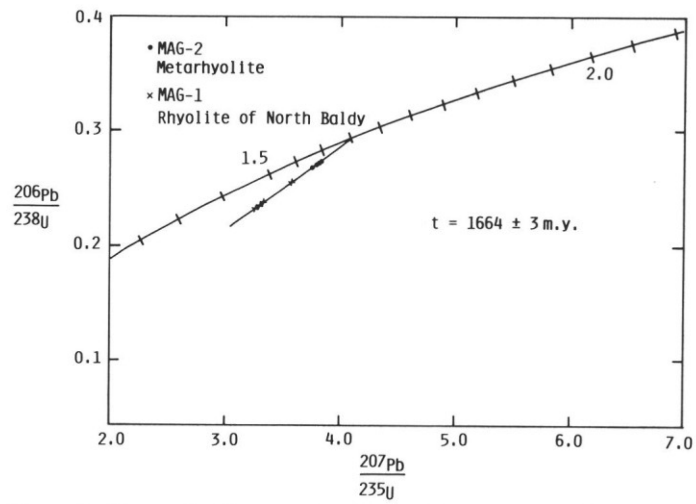

Figure 5. Concordia diagram showing the U-Pb isotopic relationships of zircons from the metarhyolite and rhyolite of North Baldy, Magdalena Mountains.

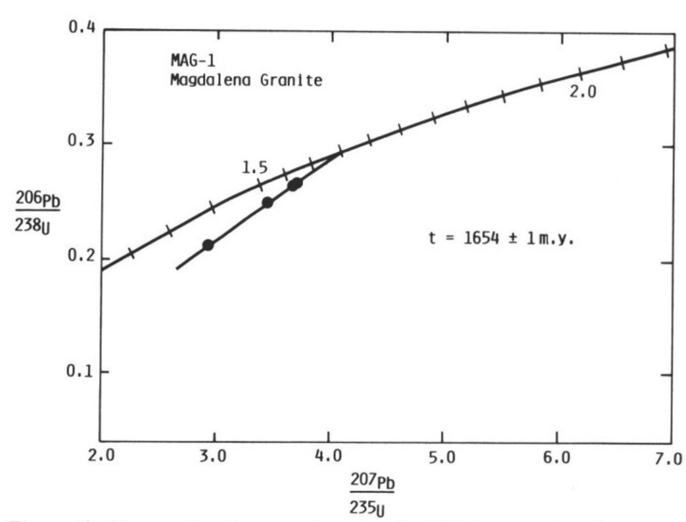

Figure 6. Concordia diagram showing the U-Pb isotopic relationships of zircons from the Magdalena Mountains.

ages do not always correspond to any known geologic event, such as igneous activity or regional uplift. Thus, caution is advised in attaching significance to Rb-Sr whole rock ages and calculated initial '7Sr/86Sr ratios in central New Mexico.

LEMITAR MOUNTAINS

The Lemitar Mountains are located approximately 11 km northwest of Socorro, New Mexico; Proterozoic rocks crop out along the eastern flank of the range (fig. 1). McLemore (1980) has described the geology of the Proterozoic rocks exposed in the Lemitar Mountains and Figure 7 is adapted from her geologic map. The major Proterozoic rock types exposed in the Lemitar Mountains are two granite plutons, a diorite/gabbro pluton, and a minor amount of metasedimentary rocks. Small bodies of muscovite-bearing pegmatite, quartz veins, and mafic dikes are also present.

The oldest Proterozoic rocks in the Lemitar Mountains are the metasedimentary rocks that are best exposed along Corkscrew Canyon (fig. 7). These rocks consist of quartzo-feldspathic biotite schists with interlayered quartzite. No primary sedimentary structures are preserved in these rocks. Protoliths of these metasedimentary rocks probably included feldspathic sandstone and arkose.

The metasedimentary sequence in the Lemitar Mountains is poorly exposed. In Corkscrew Canyon, macroscopic isoclinal folds in a metamorphic foliation defined by biotite are observed (fig. 9). Lithologic layering is defined by alternating quartz-rich and biotite-rich layers and is subparallel to the biotite foliation. Both field and petrographic evidence suggests that original lithologic layering is transposed parallel to metamorphic foliation. The transposed foliation has been isoclinally folded at least once and then broadly warped by a later folding event. Lack of marker horizons and poor outcrop hamper detailed structural studies; however, it is certain that estimates of stratigraphic thicknesses or environments of deposition are unreliable until a complete understanding of structural geometries in these rocks has been obtained.

The Lemitar diorite/gabbro makes up about 20 percent of the Proterozoic outcrop in the Lemitar Mountains. The diorite/gabbro intrudes quartz-biotite schists north of Corkscrew Canyon and is intruded by a large granite pluton (the Polvadera granite), and several small biotite granite plutons. At the southern end of the Proterozoic outcrops in the •Lemitar Mountains a foliated biotite granite intrudes the metasedimentary sequence (fig. 7). Analysis of zircons from this granite yield an age of 1648 ± 3 my. (fig. 8). This age provides a minimum age for deposition of the metasedimentary rocks.

CHUPADERA MOUNTAINS

The Chupadera Mountains are located 20 km south of Socorro. Proterozoic rocks are restricted to the eastern flank (fig. 10) and include quartzo-feldspathic, pelitic, and mafic schists, a felsic porphyry, and an alkali feldspar megacrystic granite.

The quartzo-feldspathic and pelitic schists are variable in composition and often grade into one another. The quartzo-feldspathic schists are reddish orange in color and contain 75-90 percent quartz, 0-25 percent alkali feldspar, and small amounts of muscovite, biotite, and chlorite. The pelitic schists are grey in color and generally contain greater than 50 percent muscovite, 10 percent biotite/chlorite, and less than 40 percent quartz. Locally, garnet and staurolite (?) (retrograded to sericite and quartz) are present. From north to south, the pelitic schists become more banded and gneissic in character; however, mineralogically the only difference is the absence of chlorite in the gneisses. The pelitic and feldspathic units are interpreted to be metamorphosed sandstone, arkose, and siltstone. A porphyritic rock which contains 0-10 percent quartz and 5-20 percent alkali feldspar mesocrysts is believed to be an intrusive, felsic porphyry. The metasedimentary rocks are intruded at

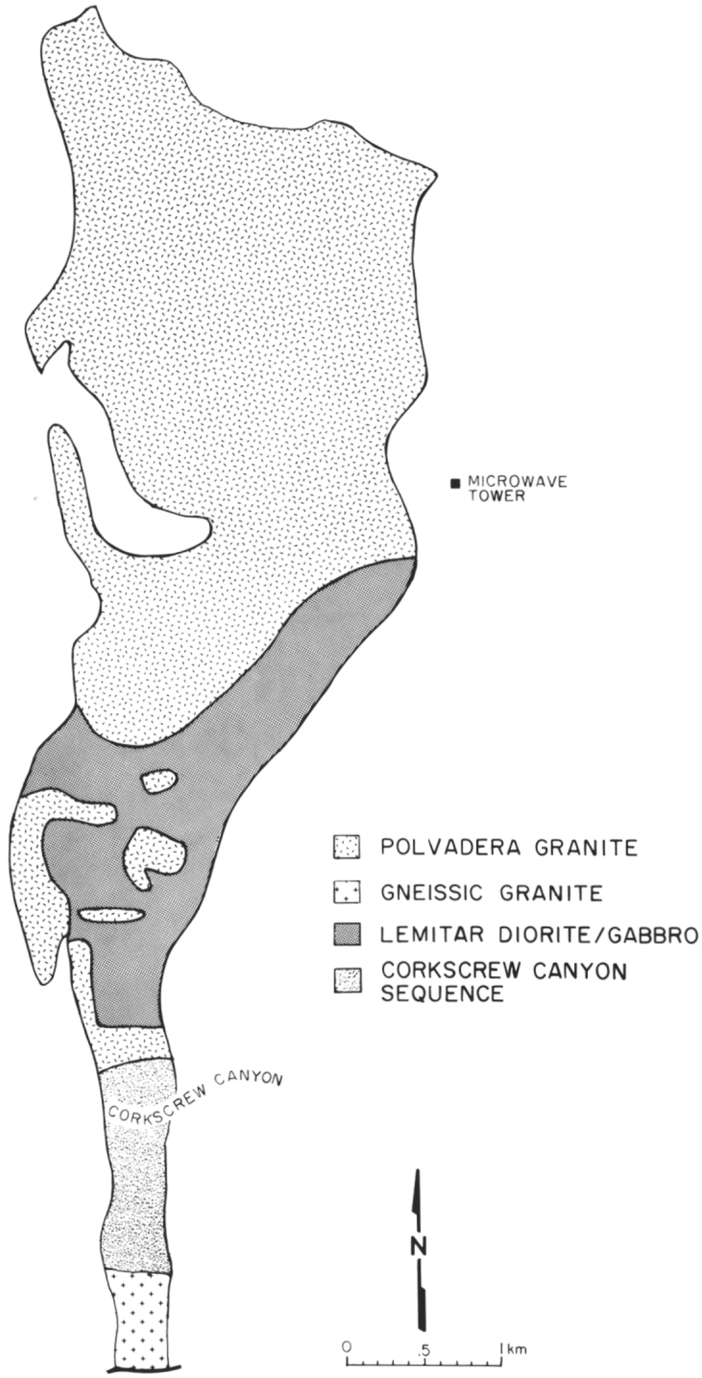

Figure 7. Generalized geologic map of the Lemitar Mountains (after McLemore, 1980).

the southern end of the exposure by a foliated alkali-feldspar megacrystic granite.

Although a detailed structural analysis of the Precambrian exposures in the Chupadera Mountains is not complete, there is abundant evidence for several episodes of folding. No primary sedimentary structures are preserved and compositional layering is subparallel to metamorphic foliation. The map pattern suggests at least one early west-northwest-trending episode of isoclinal folding followed by northeast-trending open folding. Complex fold patterns can be observed in many outcrops (fig. 11). Elongated mineral aggregates and intersecting cleavage and foliations form prominent lineations (fig. 12). Compositional layers within the units are lenticular and small isoclinal folds of layering are

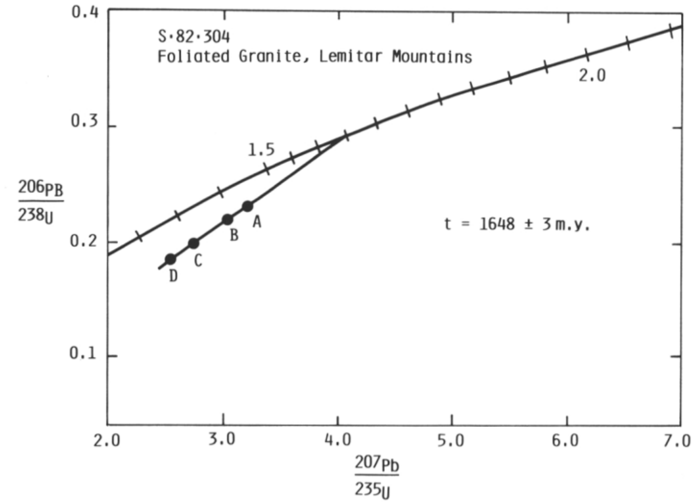

Figure 8. Concordia diagram showing the U-Pb isotopic relationships of zircons from the foliated gneissic granite, Lemitar Mountains.

present locally; these observations are indicative of transposition during isoclinal folding.

Zircons separated from the megacrystic granite at the southern end of the exposure yield an age of 1659 ± 3 m.y. (fig. 13). This is a minimum age for the deposition of the supracrustal rocks in the Chupadera Mountains. It is not known whether the foliated nature of this granite is related to penetrative deformation or to depth of emplacement. In the future, distinguishing between pre-, syn-, and post-tectonic granites in the field in conjunction with U-Pb geochronology will enable the timing of deformation and metamorphism to be constrained in central New Mexico.

DISCUSSION

Proterozoic rocks exposed in the Magdalena, Lemitar, and Chupadera Mountains consist dominantly of quartz-rich metasedimentary rocks with metavolcanic rocks abundant in the Magdalena exposures only. These sequences are intruded by hypabyssal porphyries, gabbros, and granites. Contrary to previously published reports, the supracrustal rocks have undergone a complex structural history involving isoclinal folding and transposition of bedding. Although outcrop- or map-scale folds are difficult to identify and outcrops are poor, the need for detailed structural studies is obvious.

U-Pb zircon ages on both metavolcanic rocks and granites in the Socorro area indicate an age of about 1650± 10 my. for the accumulation of the supracrustal sequence and their intrusion by granite plutons. These ages are similar to those obtained from other areas in central New Mexico. U-Pb zircon ages of 1650-1680 my. have been obtained from metavolcanic rocks in the Manzano Mountains (Bowriffi and Condie, unpublished data) and a granite and a felsic metavolcanic rock from the Zuni Mountains yield ages of approximately 1650 m.y (Bowring and Condie, 1982). The U-Pb ages presented here are olde than previously published Rb-Sr isochron ages for the rocks in th(Magdalena Mountains. Thus, tectonic models that use the timing o plutonism and metamorphism based on Rb-Sr ages should be considere(with caution.

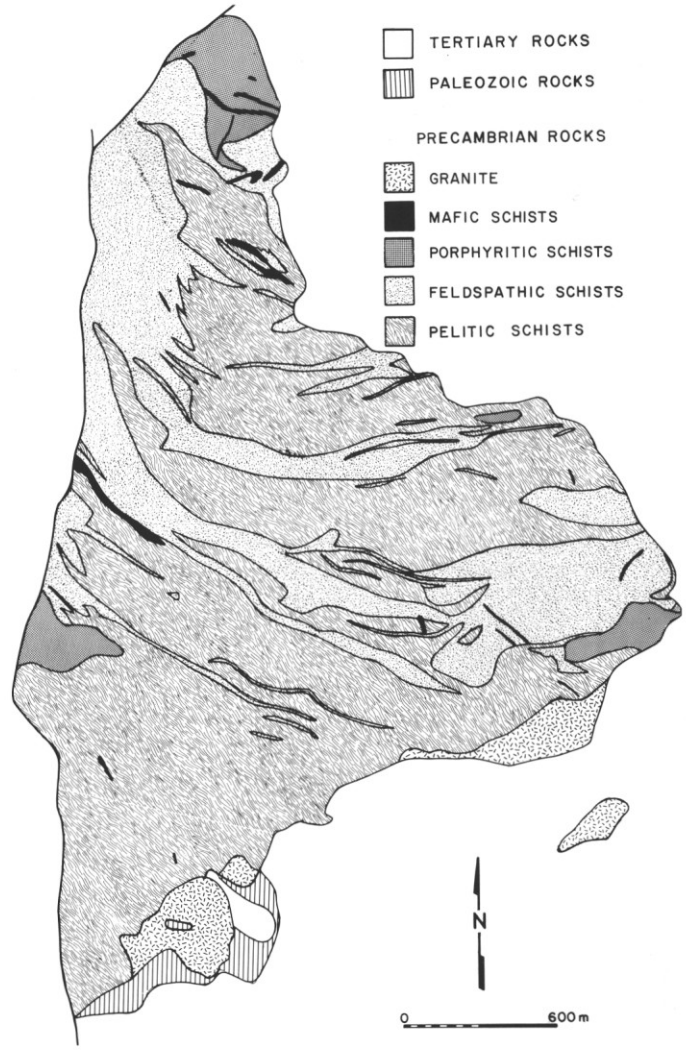

Figure 10. Generalized geologic map of Proterozoic rocks in the Chupadera Mountains (after Kent, 1982).

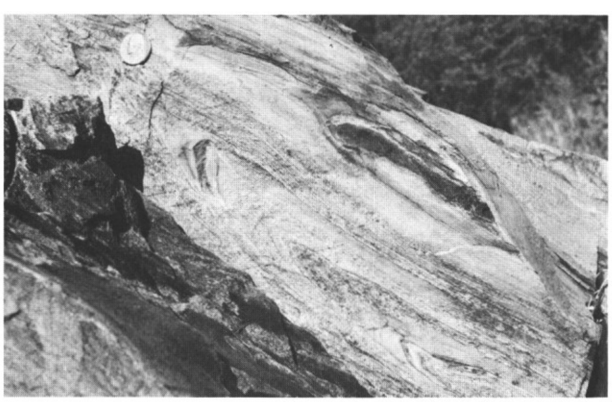

Figure 9. Complex isoclinal folding in metasedimentary rocks, Corkscrew Canyon area, Lemitar Mountains.

Figure 11. Complex isoclinal folding in pelitic schists, Chupadera Mountains.

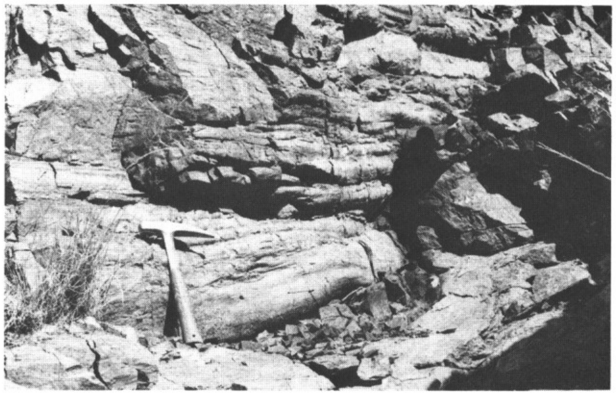

Figure 12. Prominent lineation (mullions?) in pelitic schists, Chupadera Mountains.

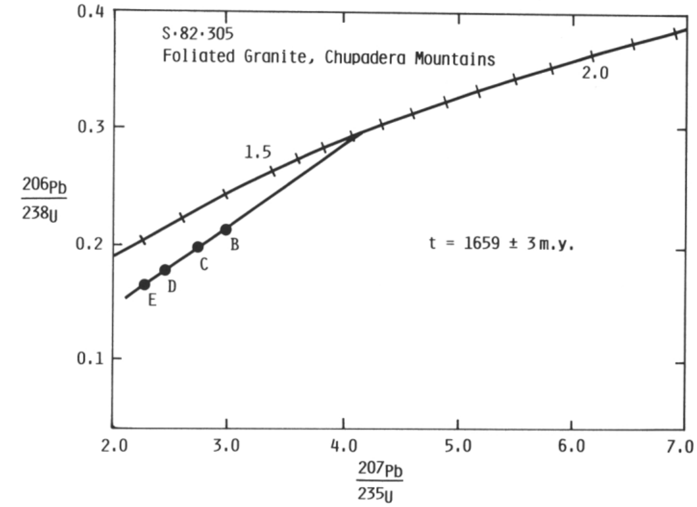

Figure 13. Concordia diagram showing the U-Pb isotopic relationships of zircons from the foliated granite, Chupadera Mountains.

Preliminary geochronology from central New Mexico suggests thd a large portion of the exposed Proterozoic crust in central New Mexicc formed during the period from about 1640-1680 m.y. However, unti detailed geologic and structural studies, in conjunction with precis(zircon chronology are completed, caution must be applied to any mode for the evolution of Proterozoic rocks in New Mexico involving precis(correlation of rock units between mountain ranges or into neighborin states.

Condie and Budding (1979) and Condie (1982) proposed two differem models for the evolution of the Proterozoic rocks in central and southerr New Mexico. Although they are the only workers to attempt a synthesis of published data, their models are based on simplified stratigraphic successions and do not integrate the deformational histories or structural geometries of the rocks with their proposed paleotectonic environments. A comprehensive model for the Proterozoic evolution of central New, Mexico must compare in detail the lithologies, deformational histories. and geochronology of isolated exposed blocks.

ACKNOWLEDGMENTS

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