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1988, pp. 99-107. https://doi.org/10.56577/FFC-39.99

in:

Cretaceous and Laramide Tectonic Evolution of Southwestern New Mexico, Mack, G. H.; Lawton, T. F.; Lucas, S. G.; [eds.], New Mexico Geological Society 39th Annual Fall Field Conference Guidebook, 216 p. https://doi.org/10.56577/FFC-39

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GEOCHRONOLOGIC STUDIES OF THE FLORIDA MOUNTAINS, NEW MEXICO

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Abstract—Numerous geochronologic studies have been carried out on samples from the Florida Mountains, southern New Mexico. Early results indicated a range of dates for Precambrian to Mesozoic syenite-alkali granite core rocks, although questionable assumptions were involved in some of these studies. The core igneous rocks are in fault contact with sedimentary rocks in much of the Florida Mountains, but are unconformably overlain by sedimentary rocks elsewhere. These sedimentary rocks are Cambro-Ordovician and younger, placing a limit on the age of some of the igneous rocks.

K-Ar dates from the igneous core rocks range from 418 to 555 my, while a mineralized monzonite dike yielded an age of 61.5 my and an andesite dike 27.9 my. These last two ages may be associated with mineralization in the area. Rb-Sr dates range from 380 to 470 my and cluster around 400–420 my. These ages are defined by scattered linear arrays suggestive of open system conditions for the rocks, and this is supported by a wide range of apparent initial $^{87}Sr/^{86}Sr$ ratios for presumably coeval rocks. U-Pb dates on zircons from the Floridas yield a 514 ± 3 my concordia intercept from our studies, consistent with U-Pb dates reported by Evans and Clemons (1987) of 503 my.

Collectively, the geochronologic data argue for Paleozoic plutonism at about 500–515 my, with a resetting event that affected Rb-Sr systematics in the core syenite-alkali granite and overlying Bliss Formation, possibly at about 400 my. The nature of this resetting event is not well understood. The geochronologic data also support the extension of Paleozoic plutonism proposed by Loring and Armstrong (1980) into southern New Mexico, as well as possible extension of the Texas lineament into the area from the east, which may provide valuable information on Paleozoic plate boundary positions.

INTRODUCTION AND PREVIOUS WORK

The Florida Mountains in southern New Mexico have attracted modest attention over the last two decades. They consist of a core of syenites, alkali granites and diorite-gabbros, all of controversial but possibly similar age, together with some granitic gneiss (Matheney, 1984). These units are overlain by lower Paleozoic and younger sedimentary and volcaniclastic rocks, and are cut by Tertiary rhyolitic and andesitic dikes. Although many of the contacts between core rocks and Paleozoic sedimentary rocks are faults, a few nonconformable contacts provide stratigraphic age control for some of the core rocks. Arkose, assigned as Cambro-Ordovician Bliss Formation (Lochman-Balk, 1958), rests nonconformably on eroded granite west of Capitol Dome (Fig. 1), and on syenite in the central part of the range, southeast of Capitol Dome. Although no fossils are known from the arkose in the Florida Mountains, this unit is gradationally overlain by the Ordovician El Paso Formation, which includes a diverse and diagnostic Lower Ordovician fauna in the Florida Mountains (Lemone, 1974). Thus, the stratigraphic control is sufficient to document that Cambrian to Ordovician rocks nonconformably overlie the core rocks in some places. Such stratigraphic control is not available, however, for the large granite body south of a major reverse fault north and west of Gym Peak (Fig. 1).

The ages of the core igneous rocks have been the subject of several studies prior to this work, and the conclusions have been diverse, often depending mostly upon the strength of the stratigraphic controls acknowledged by the workers at the time. Corbitt (1971) and Corbitt and Woodward (1973) assigned a Mesozoic(?) age to the syenites and southern granite (mapped as syenite) based on very tenuous field relations, while they assigned a Precambrian age to the northern granite. Brookins (1974), using several altered samples collected by Corbitt, reported a wide range of Rb-Sr ages from about 400 my for syenites and some granites to over 1000 my for other granites, although he was not able to completely dismiss Mesozoic emplacement for some syenitic material. He also included hornblende K-Ar ages obtained by R. E. Denison (Table 1) that range from 418 to 555 my. In a later study, Brookins (1980) reported both near-400 my ages and near-1500 my ages for the core igneous rocks. The latter were based on commercially obtained data and have been shown (Matheney, 1984) to be in serious error; corrected ages are near 400 my.

Recently, Matheney (1984) conducted a rigorous study of the Rb-Sr systematics of the Florida Mountains igneous core rocks, and his data are discussed in this report. Independently, Clemons (1982, 1984) and Clemons and Brown (1983) assigned a Precambrian age to the core rocks. Later, working with K. V. Evans of the USGS, Clemons (1985) reported U-Pb ages for the syenite and granite of 550 and 525 my, respectively, which have been refined to ages ranging between 495 and 523 my (Evans and Clemons, 1987).

Rb-Sr and K-Ar data have also been obtained at the University of Arizona by M. Shafiqullah and P. E. Damon (unpublished data, 1983), and U-Pb data have been obtained by E. T. Wallin of the University of Kansas (unpublished data, 1987). These data are also discussed in this report.

The data now available yield a cluster of ages in the range of just under 400 my to just over 500 my, supporting Loring and Armstrong's (1980) proposed extension of Early Paleozoic alkalic plutonism into southern New Mexico, or possibly extension of the Texas lineament into the area.

PRESENT STUDY

Standard methods were used for Rb-Sr, K-Ar and U-Pb determinations. Some details are given in Matheney (1984), and the balance will be presented in a forthcoming paper (Matheney et al., in preparation).

TABLE 1. K-Ar dates from syenites and gabbros, Florida Mountains. Data by R. E. Denison, written communication, in Brookins (1974).

Sample No.	K-Ar Age (Ma)	Rock
1625H-a	418 ± 8	Quartz syenite
1625-b	419 ± 8	Quartz syenite
1654H-a	555 ± 11	Hornblende gabbro
1654H-b	545 ± 11	Hornblende gabbro
1654H-c	530 ± 20	Hornblende gabbro

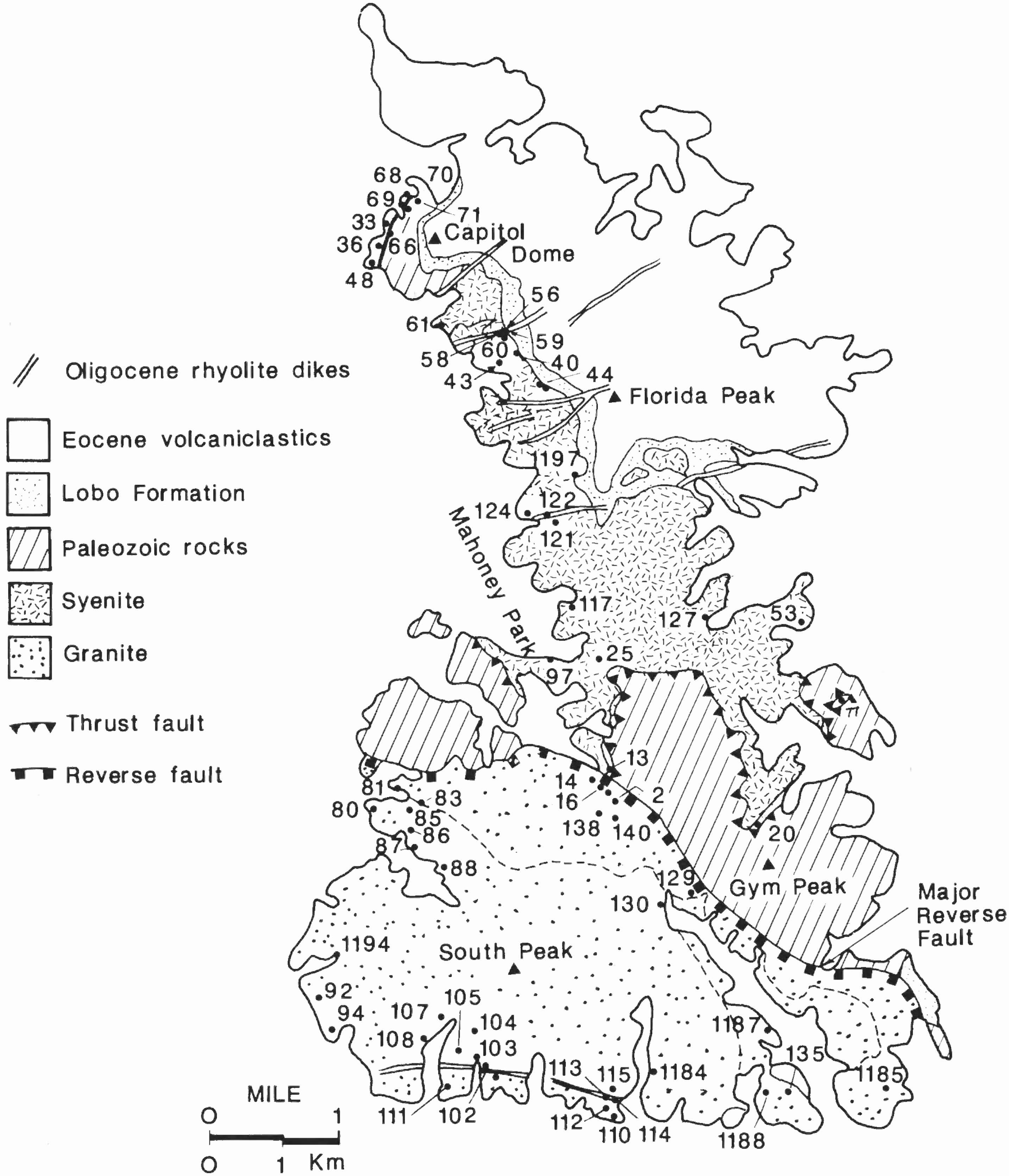

FIGURE 1. Generalized geologic map of the Florida Mountains showing sample locations. Modified from Clemons (1982, 1984) and Matheney (1985).

Matheney (1984) studied 71 samples from the Florida Mountains for their Rb-Sr systematics, including 50 core igneous rocks, four Bliss Formation(?) rocks and seven Tertiary dike rocks. The sample locations are given in Figure 1, together with the locations for Shafiqullah and Damon's samples. Matheney's Rb-Sr data are given in Table 2, while the Rb-Sr and K-Ar data of Shafiqullah and Damon are given in Tables 3 and 4, respectively. The U-Pb data of Wallin are given in Table 5; the field location for this sample is identical to location 97 of R. K. Matheney (Fig. 1).

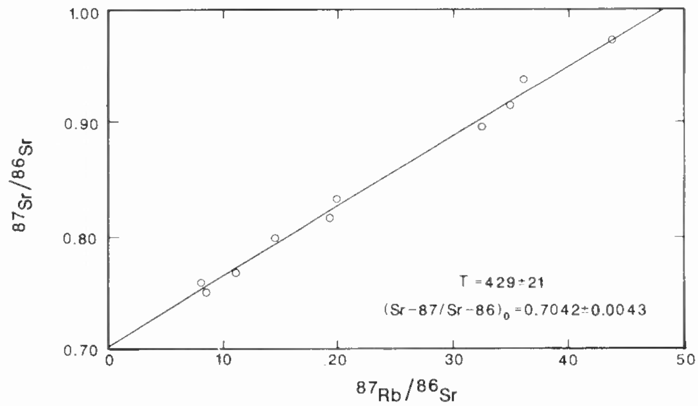

FIGURE 2. Rb-Sr isochron for granite and alkali granite samples (see text for details).

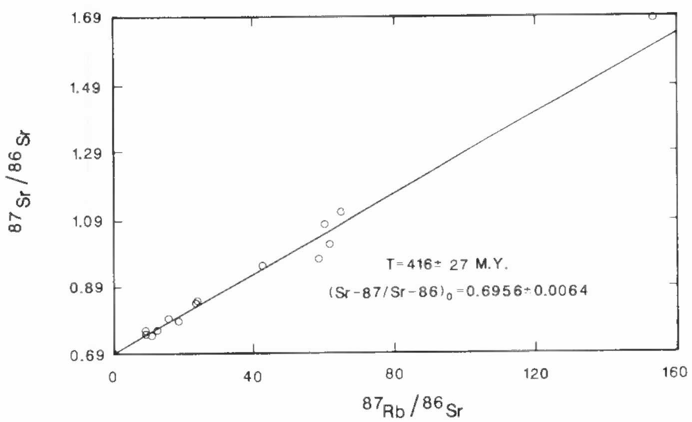

FIGURE 3. Rb-Sr isochron for quartz syenite samples (see text for details).

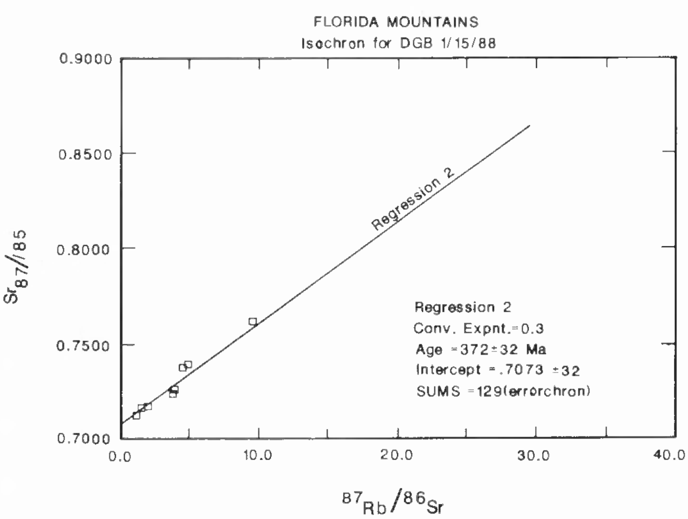

FIGURE 4. Rb-Sr isochron for syenite samples (see text for details).

The Rb-Sr isochrons are presented in Figures 2 to 9. These are more properly called scatterchrons (cf. Brooks et al., 1972) due to the large scatter in the data. Two main points are evident from these plots: (1) the dates fall approximately in the 380–450 my range, firmly in the Paleozoic; (2) apparent $^{87}Sr/^{86}Sr$ initial ratios calculated from a least-squares treatment of the data are occasionally paradoxical, falling below the 0.699 value believed to characterize the primordial earth (Faure, 1986). These points are discussed below.

DISCUSSION

Of the K-Ar dates now available (Tables 1 and 4), the oldest, at 530 to 555 my, are for hornblendes separated from gabbro (Brookins, 1974).

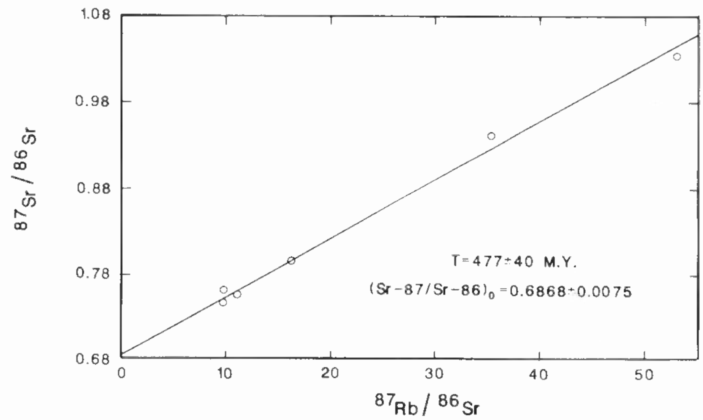

FIGURE 5. Rb-Sr isochron for aplite samples (see text for details).

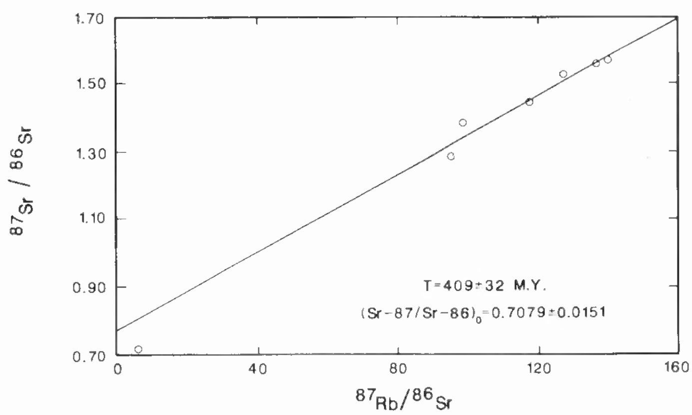

FIGURE 6. Rb-Sr isochron for samples previously described as Precambrian in age (see text for details).

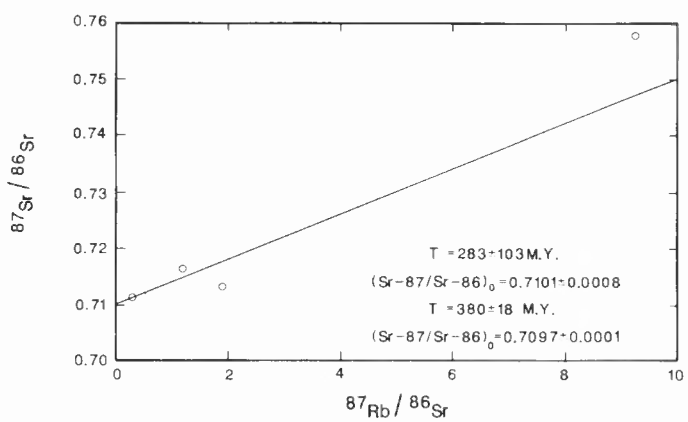

FIGURE 7. Rb-Sr isochron for samples from the Bliss Formation (see text for details).

TABLE 2. Rb-Sr data for Florida Mountains whole rocks. See Figure 1 for sample locations.

Sample Number	Rb (ppm)	Sr (ppm)	($^{87}Rb/^{86}Sr$)	($^{87}Sr/^{86}Sr$)	Model Age
pCg 3	155.70	31.30	14.53	0.79816	
pCg 14-1	127.92	11.60	32.50	0.89480	
pCg 14-2	128.97	10.89	34.97	0.91433	
pCg 16	133.40	20.21	19.31	0.81515	
pCg 81	144.75	11.86	36.12	0.93715	
pCg 129	101.34	34.55	8.52	0.75025	
pCg 138	140.87	9.52	43.94	0.97128	
pCg 1185	148.10	21.8	19.90	0.832	
pCgN 33-1	163.73	58.14	8.19	0.75886	
pCgN 33-2	159.05	57.97	7.98	0.75908	
pCgN 36	166.38	43.72	11.08	0.76707	
pCgN 48	137.05	47.21	8.44	0.75037	
pCgdf 80	103.69	24.69	12.22	0.75945	
pCgdf 85	107.96	20.58	15.32	0.79685	
pCgdf 86	100.45	12.43	23.72	0.84782	
pCgdf 88	125.75	33.61	10.87	0.74509	
pCgdf 111	200.86	10.25	58.20	0.97366	
pCgdf 112	196.91	9.83	60.06	1.07468	
pCgdf 115	153.96*	47.	9.52	0.75	
pCgdf 116	100.76	16.19	18.16	0.78863	
pCgdf 130	152.42	50.05	8.86	0.76048	
pCgdf 1184	146.39	10.27	42.24	0.95366	422 MY
pCgdf 1187	168.04	7.81	64.73	1.11227	451 MY
pCgdf 1188	283.77	5.85	153.70	1.68272	456 MY
pCgdf 1193	180.37	8.76	61.39	1.01655	364 MY
pCgdf 1194	148.57	18.93	23.02	0.84189	427 MY
pCgdm 83	57.85	658.05	0.26	0.70825	
pCgdm 87	52.26	285.16	0.53	0.70912	
pCgdm 94	83.69	421.49	0.58	0.71263	
pCgdm 105	64.86	503.06	0.37	0.70746	
pCgdm 107	76.88	387.20	0.58	0.71027	
pCgdm 114	143.79	450.34	0.92	0.71260	
pCs 20	132.27	84.38	4.55	0.73663	
pCs 25	117.28	221.46	1.53	0.71599	
pCs 53	135.44	99.10	3.96	0.72552	
pCs 76	190.02	43.72	9.64	0.76116	
pCs 97	84.97	198.31	1.24	0.71251	
pCs 117	85.35	121.03	2.04	0.71656	
pCs 121	94.65	72.66	3.78	0.72387	
pCs 127	158.41	92.85	4.96	0.73923	
pCs 1197	144.98	13.11	32.53	0.87516	375 MY
pCsdf 47	75.65	378.89	0.20	0.71155	
pCsdf 58	91.62	269.94	0.98	0.71349	
pCsdf 59-1	120.70	145.34	2.41	0.71884	
pCsdf 59-2	120.51	143.81	2.43	0.71857	
pCsdf 60	93.52	193.04	1.40	0.71476	
pCsdf 61	100.61	130.79	2.23	0.72697	
pCsdm 40-1	75.29	450.31	0.48	0.70978	
pCsdm 40-2	70.09	458.04	0.44	0.70979	
pCsdm 43-1-1	141.24	458.59	0.85	0.70868	
pCsdm 43-1-2	141.45	482.24	0.85	0.71204	
pCsdm 43-2	143.91	473.78	0.88	0.71980	

TABLE 2. (continued)

Sample Number	Rb (ppm)	Sr (ppm)	($^{87}Rb/^{86}Sr$) Age	($^{87}Sr/^{86}Sr$)
pCga 135	141.68	37.64	10.94	0.75540
pCgda 92	383.27	21.57	53.07	1.03412
pCgda 103	139.54	42.20	9.62	0.74694
pCgda 104	190.82	34.30	16.23	0.79536
pCsa 77	111.76	33.73	9.64	0.76116
pCsa 124	160.20	13.42	35.34	0.93961
Tr 44	176.89	202.42	2.53	0.71980
Tr 56	389.82	33.31	33.94	0.72541
Tr 102	225.05	33.08	17.65	0.73257
Tr 113	188.64	31.63	17.30	0.73479
Tr 122	258.82	99.28	7.56	0.71976
Tb 68		1301.62		0.70574
Tb 108	124.02	841.24	0.43	0.71216
OCb 13	101.23	248.99	1.18	0.71633
OCb 66	22.59	220.23	0.30	0.71129
OCb 70	21.24	32.41	1.90	0.71306
OCb 71	198.00	62.42	9.23	0.75779

* Normalized to $^{86}Sr/^{88}Sr = 0.1194$.

TABLE 3. Rb-Sr data for Florida Mountains samples (University of Arizona). See Figure 1 for sample locations. Data from Shafiqullah (1983, written report, unpublished).

Sample	$^{87}Sr/^{86}Sr$	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}S$	Rock
UARS 82-132	0.7942	126.8	23.6	15.68	Granite
UARS 82-133	0.7064	61.2	607.4	0.29	Diorite
UARS 81-136	0.7262	135.0	118.4	3.31	Monzonite
UARS 81-137	0.7090	151.0	718.0	0.61	Andesite
UARS 81-504	0.7164	124.8	218.3	1.66	Syenite
UARS 81-505	0.7184	114.8	177.6	1.87	Syenite
UARS 81-506	0.8195	151.2	23.3	18.74	Syenite
UARS 81-507	0.7442	132.2	52.8	7.27	Syenite
UARS 81-508	0.7741	104.7	27.0	11.29	Syenite
UARS 81-509	0.7655	101.8	29.2	10.14	Syenite
UARS 81-510	0.7803	142.0	30.0	13.79	Syenite
UARS 81-511	0.7175	112.0	104.2	3.10	Syenite
UARS 81-512	1.3866	506.0	14.3	109.18	Aplite

TABLE 4. K-Ar ages, Florida Mountains. Data from Shafiqullah (1983, written report, unpublished).

Sample	K-Ar age (MA)	Rock
UAKA 81-138	61.5 ± 1.4	Monzonite (feldspar separate)
UAKA 81-137	27.9 ± 0.7	Andesite dike (groundmass)

TABLE 5. Analytical data for zircon fractions.

	Fraction[1]				
	nm(-2)AA	m(-2)AA	m(-2)	m(1)	m(2)
Concentrations[2]					
U (ppm)	200.89	246.37	256.50	505.98	477.43
Pb (ppm)	17.85	21.08	21.47	32.35	27.86
Observed[3]					
Pb-206/Pb-204	5988	7937	14925	2632	2165
Radiogenetic Ratios[4]					
Pb-207/Pb-206	0.057538	0.057504	0.057604	0.057261	0.057144
Pb-2008/Pb-206	0.20876	0.20142	0.19574	0.17025	0.16757
Pb-206/U-238	0.08120	0.07862	0.07745	0.05956	0.05436
Pb-207/U-235	0.64416	0.62336	0.61517	0.47025	0.42828
Ages[5]					
Pb-206/U-238	503	488	481	373	341
Pb-207/U-235	505	492	487	391	362
Pb-207/Pb-206	512	511	514	502	497

Upper intercept age = 514 ± 3 Ma, lower intercept age = 38 ± 11 Ma

Notes:
[1] nm = nonmagnetic, m = magnetic, numbers in parentheses indicate side tilt used on Franz separator at 1.4 amps; AA = air abraded fraction
[2] corrected for analytical blank
[3] measured ratio uncorrected for blank or radiogenic Pb
[4] corrected for blank and nonradiogenic Pb; U corrected for blank
[5] ages in Ma

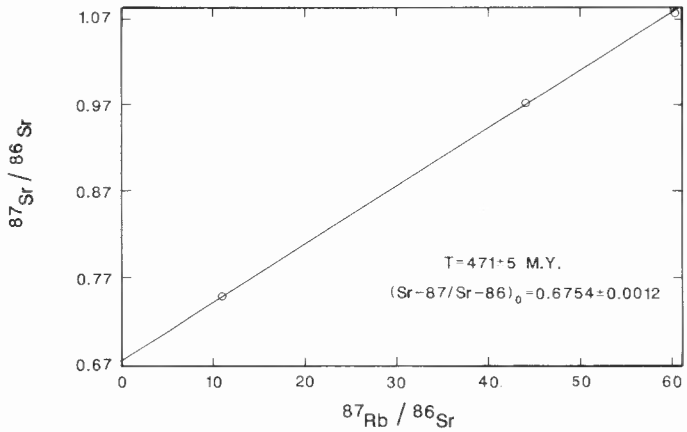

FIGURE 8. Rb-Sr internal isochron (minerals) for granite sample pCg 138 (see text for details).

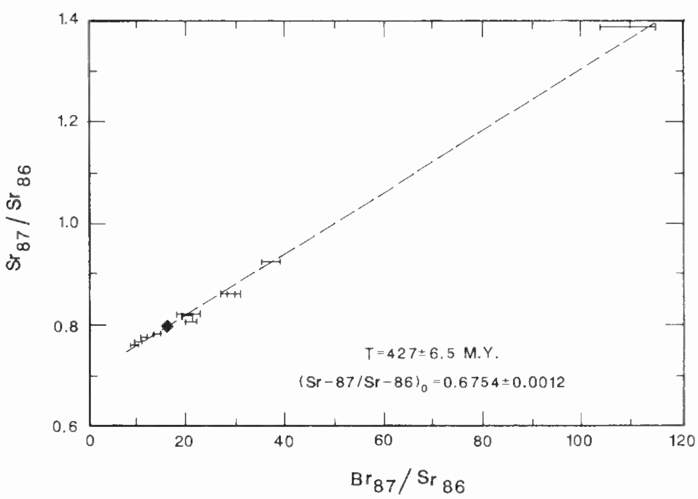

FIGURE 9. Composite Rb-Sr isochron for Florida Mountains data (see text for details).

Because hornblende normally exhibits a strong retentivity for ^{40}Ar, the pre-500 my dates for these three samples may be significant, and could record the age of formation of the gabbro. Nevertheless, hornblendes separated from a quartz syenite yielded ages of 418–419 my (Brookins, 1974), even though stratigraphic controls make it evident that they are much older. Apparently, the K-Ar systematics of the syenite, at least, have been reset. It is not known at this time why the K-Ar systematics of the gabbro were not resent to a similar degree. Since syenite intrudes gabbro, the gabbro would have been present when the syenite was disturbed.

The new zircon U-Pb dates (Table 5; Fig. 10) are also from a syenite (sample location 97, Fig. 1). The zircons are extremely uniform with regard to color (light pink), high clarity and paucity of inclusions. Zircons with high magnetic susceptibility and cloudy overgrowths were excluded from this study. The zircons exhibit both euhedral-to-subhedral forms and anhedral forms. Both varieties range in size from 200 to 500 μm, but size does not correlate with morphology. Petrography reveals a minor component of metamict, inherited zircon cores, but these cores account for less than one percent of the zircon sample material. The U-Pb concordia plot (Fig. 10) gives an age of 514 ± 3 my, based on the upper concordia intercept. The lower concordia intercept of 38 ± 11 my corresponds to late Laramide magmatism, but this may be coincidental and we attribute it no special significance.

The body of U-Pb zircon data that now exists (this work; Evans and Clemons, 1987) indicates that the syenite crystallized between 500 and

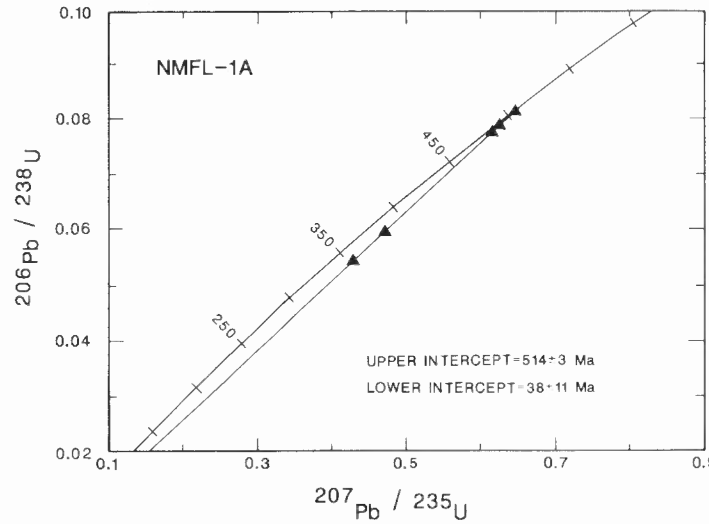

FIGURE 10. U-Pb concordia diagram for Florida Mountains samples (see text for details).

550 my. Minor variability (several my) in the ages of different syenite samples may be real, or alternatively, may result from variable proportions of inherited zircon and different zircon populations. Unlike the K-Ar ages, these U-Pb ages can be reconciled with the stratigraphic constraints available for the syenite and appear to confirm its Paleozoic origin. The significance of this will be discussed later.

The bulk of the geochronological data is for Rb-Sr systematics. The study by Matheney (1984), including reanalysis of some samples reported as Precambrian by Brookins (1980) and shown to be inaccurate due to faulty commercial analyses, demonstrates that most syenites and alkali granites fall in the 380–450 my range (Figs. 2–8). Further, the newly reported Rb-Sr data of Shafiqullah and Damon (Table 3; Fig. 9) support this finding. Although such ages may be marginally consistent with the K-Ar ages for the syenite, they are totally at odds with the available U-Pb ages and stratigraphic control provided by the El Paso Formation. We attach little significance to the stratigraphic control attributed to the Cambro-Ordovician Bliss Formation, since the assignment of this arkose to the Bliss in the Florida Mountains is thus far based only on its position beneath the El Paso and very gross lithologic similarity to the Bliss elsewhere. This arkosic unit in the Floridas contains abundant fragments of syenite and alkali granite, alkali feldspars and quartz. Since it rests on syenite and alkali granite, it may very well have been derived locally, and may not correlate with the Bliss elsewhere. The lack of paleontological evidence does not allow the unit to be firmly assigned to the Early Ordovician. This indicates, of course, that if the 514 my U-Pb date obtained by Wallin is to be regarded as a formational age, the core igneous rocks must have been uplifted and eroded very rapidly prior to deposition of the arkose. Matheney (1984) attempted Rb-Sr dating of these arkosic rocks (Fig. 7) and noted that three of the four samples yielded a scatterchron of 380 ± 18 my, consistent with the dates on many of the igneous rocks. If the stratigraphy is accepted, it is clear that this cannot be the age of provenance, and whatever reset the Rb-Sr systematics of the plutonic rocks must have acted here as well. A fourth sample of arkose falls well off the scatterchron defined by the other three (see Fig. 7); if it is included in the least-squares treatment, an age of 283 ± 103 my is obtained (Matheney, 1984).

Our inference that the Rb-Sr systematics of essentially all of the plutonic rocks in the Florida Mountains have been upset has so far relied heavily on stratigraphic arguments. Unrecognized faults could nullify these arguments, and the Florida Mountains are intensely faulted (Clemons, 1982, 1984, 1985; Clemons and Brown, 1983). Although the mapping of Clemons (1984, 1985) and Clemons and Brown (1983) is believed to be excellent, evidence for resetting can be found within the Rb-Sr data set itself. This diminishes the need to rely on stratigraphic interpretations of this complexly faulted terrane to propose a perturbation of Rb-Sr systematics.

It is apparent from inspection of the Rb-Sr whole-rock isochrons for the syenites and alkali granites, including the aplites (Figs. 2 to 6 and 9), that although the dates generally range only between 380–450 my, there is a wide variety of apparent initial $^{87}Sr/^{86}Sr$ ratios, including some that plot below meteoritic values. This is also true within individual samples. Matheney (1984) prepared mineral separates from four whole rocks to test them for closure to Rb and Sr. His results showed scatter from 282 ± 106 my to 566 ± 21 my, with apparent initial ratios ranging between 0.7085 and 0.6754. An example is given in Figure 8 (from Matheney, 1984). The mineral isochrons show scatter comparable to that of the whole-rock isochrons, and plot well within the fields of the whole-rock scatterchrons for the syenites and alkali granites from which the samples were obtained (Matheney, 1984).

The scatter in dates and apparent $^{87}Sr/^{86}Sr$ initial ratios, plus low apparent initial ratios, make it obvious that some type of resetting has occurred. One way to test for perturbations of Rb-Sr systematics is to examine a plot of $^{87}Sr/^{86}Sr$ vs. 1/Sr for possible indications of mixing of rock Sr with Sr from some other reservoir (Faure, 1986). This is shown as Figure 11 (from Matheney, 1984). A linear array is noted, supporting the *possibility* of mixing, but caution must be exercised in interpreting this as a clear indication of simple mixing. Matheney (1984) observed that there is a relatively narrow range of Rb concentrations for the Florida Mountains whole-rock samples, but a wider range of Sr concentrations. Furthermore, the $^{87}Sr/^{86}Sr$ ratios correlate inversely with Sr content. Under these conditions, *any* group of samples with nearly constant total Rb will yield a liner relation between $^{87}Sr/^{86}Sr$ and 1/Sr, and the linear array in Figure 11 may be fortuitous. Were it definitely a mixing line, then the scatterchrons could be interpreted as "fossil" or "pseudo-isochrons" (Faure, 1986), with no age significance whatsoever. Ordinarily, such mixing produces fictitious isochrons which are too old, rather than too young as in the present case, but this is because the second Sr reservoir involved in mixing usually is enriched in ^{87}Sr. In any case, we are uncertain whether the range of Rb concentrations for the core rocks is actually narrow enough to nullify the significance of the diagram, and we still consider mixing a possibility here.

The mechanism of resetting of the Rb-Sr systematics is problematic in the present case. Essentially, only a few processes are possible: addition or subtraction of isotopically normal Rb, or addition or subtraction of isotopically normal or ^{87}Sr-enriched Sr. The difficulty arises in attempting to envision a scenario involving Rb or Sr addition or subtraction which produces both a lower apparent age *and* a lower apparent $^{87}Sr/^{86}Sr$ initial ratio. We can say, however, that such a process would probably have involved a fluid. Although the core igneous rocks are not metamorphosed, evidence of fluid-phase interactions is ubiquitous in outcrop, thin-section and trace-element geochemistry. Outcrops are commonly stained red or black, and often have poor mechanical integrity. Thin-sections show secondary fluid inclusions in quartz (E. Roedder, pers. commun. to R. K. Matheney, 1985), altered mafic minerals, some feldspars partially altered to clays and minute hematitic inclusions in feldspars, causing a brick-red coloration (Matheney, 1984). The presence of this hematite indicates that oxidizing solutions penetrated the feldspar grains. In general, the rocks resemble classical red-rock granophyres such as those known from the Precambrian (Taylor, 1967).

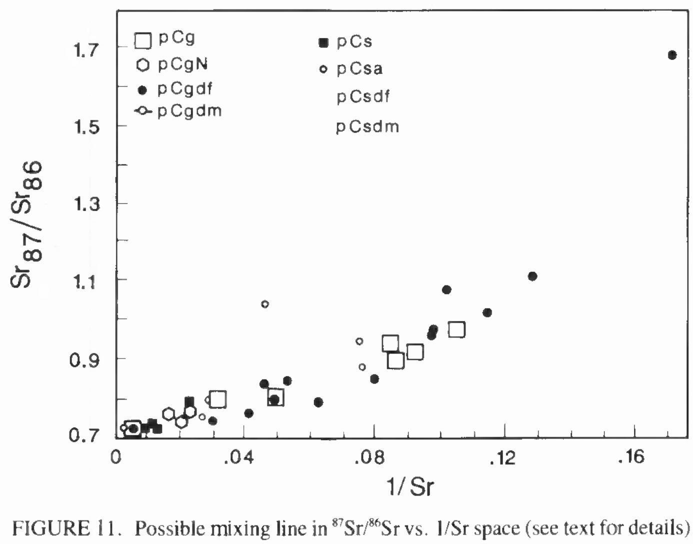

FIGURE 11. Possible mixing line in $^{87}Sr/^{86}Sr$ vs. 1/Sr space (see text for details).

Additionally, the syenites and alkali granites of the Florida Mountains have widely varying Th/U ratios, and are highly depleted in both Th and U compared to most other alkaline rocks (Matheney, 1984; Brookins et al., 1978; the detailed trace-element, stable-isotope and other data will be presented elsewhere [Matheney and Brookins, in preparation]). If interpreted as Th and U loss, these results, too, indicate pervasive involvement of a fluid phase. There is good reason to suspect that such fluid interactions, particularly when they involve brines, can produce ion-exchange reactions in feldspars (O'Neil and Taylor, 1967), and thus the opportunity probably would have existed for wholesale redistribution and exchange of Rb and/or Sr in feldspar. Since both mafic minerals, which are richest in Sr, and felsic minerals, which are richest in Rb, show alteration, we consider that some redistribution of both Rb and Sr is likely.

Matheney (1984) found Sr loss to be an appealing concept, since the Sr concentrations for most of the felsic core rocks in the Florida Mountains are well below Faure and Powell's (1972) worldwide averages for syenites and granites, with many samples having total Sr less than 15 ppm (see Table 2). Furthermore, he realized that Sr loss could be regarded as mixing a "negative component" with the original rock Sr, explaining the linear relationship observed in the mixing diagram (Fig. 11). In an isochron diagram such as Figure 5, loss of normal Sr from a given sample would shift its $^{87}Sr/^{86}Sr$ to higher values (i.e., to the right). If all samples were affected to a similar degree, the shift would appear most dramatic in samples which originally had the lowest Sr concentrations. Thus, neglecting differences in Rb concentrations, samples originally plotting at high $^{87}Sr/^{86}Sr$ values on an isochron diagram would be shifted to the right more than samples originally plotting at lower $^{87}Sr/^{86}Sr$. In principle, this sort of process alone could reduce the slope of the isochron, thus reducing the apparent age of a suite of samples. Additional slope lowering would occur if radiogenic ^{87}Sr were lost at a higher rate than normal Sr, as this would shift a data point to a lower $^{87}Sr/^{86}Sr$ on the diagram. This seems reasonable since radiogenic ^{87}Sr forms from decay of radioactive ^{87}Rb, and thus exists in a metastable site. Certainly, radiogenic ^{87}Sr is known to be more mobile than normal Sr (Faure, 1987).

If not totally systematic, this disruption alone may account for the very low apparent initial $^{87}Sr/^{86}Sr$ ratios, since these are merely extrapolations of a best-fit line (bear in mind that no anomalous $^{87}Sr/^{86}Sr$ ratios have ever actually been measured). Further scatter and slope adjustments might arise from addition of Rb to the sample suites, although Matheney (1984) regarded the addition of much Rb to the samples to be unlikely, based on considerations of the K/Rb ratios. This problem of possible alkali metasomatism is unresolved.

The timing of the Sr disruption is an interesting question. The syenite K-Ar dates fall near the low end of the range of Rb-Sr dates for the core igneous rocks. It seems unlikely that a Tertiary hydrothermal event, such as may have accompanied emplacement of the rhyolitic and andesitic dikes, would have partially reset Rb-Sr and K-Ar systematics to the same degree. Argon, as an inert gas, is quite mobile once liberated from a mineral site, and tends to be lost more easily than Rb or Sr in thermal events (Faure, 1986). It seems more likely that the K-Ar system was completely reset at about 418 my, and that the Rb-Sr system was only partially disturbed at about the same time. It would be instructive to have Rb-Sr mineral isochrons and U-Pb dates for the Florida Mountains gabbro, since this unit gives plausible K-Ar ages and may thus have escaped the resetting event. Alternatively, it too may have been altered. Denison (in Brookins, 1974) regarded the hornblende K-Ar ages from the gabbro as suspect, presumably because of the possibility that these hornblendes had picked up excess radiogenic Ar sometime since their crystallization. This was a reasonable inference, since Corbitt's (1971) map shows gabbro intrusive into syenite, instead of the other way around (Clemons, 1984). The presence of excess Ar in the gabbro would have explained this paradox while leaving the hornblende K-Ar dates in conformity with the Rb-Sr dates already available from this unit. Of the three radiometric systems employed in this study, the U-Pb system is the most likely to yield the crystallization ages of these rocks under the present circumstances. While Rb-Sr and K-Ar systematics can be upset almost any time in the history of a rock, the U-Pb systematics of zircons are less susceptible to disruptions early in their histories. This is because young zircons are quite refractory and will have suffered little radiation damage for their first several millions of years, effectively protecting them from remobilization of U, Th, Pb and intermediate radiogenic daughter products (Faure, 1986). Furthermore, the U-Pb concordia method (Fig. 10) actually utilizes the phenomenon of elemental mobility to model the age of a rock. It is conceivable that the original crystallization age of rocks can be interpreted from a concordia diagram even when the rocks have undergone two or more episodes of alteration metamorphism.

With all these considerations in mind, the following sketch of the geologic history of the igneous core rocks emerges:

1. Mafic intrusives and extrusives were emplaced at about 540 my.
2. The parent magma may have differentiated to produce the syeniite and alkali granites, which in turn were emplaced around 515 my.
3. The K-Ar systematics of the syenite (and alkali granite?) were reset at about 419 my while the gabbro somehow escaped major resetting. The Rb-Sr systematics of the syenite and alkali granite were only partially reset at this time.
4. The resetting was accomplished by a fluid phase, which also produced mineralogic changes as well as trace-element and other changes (stable isotopic investigations of these rocks are now underway [Matheney and Brookins, in preparation]).
5. The Rb-Sr partial resetting was probably mostly produced by Sr loss, although some Rb mobility is also likely.
6. The U-Pb system of the zircons remained essentially intect, since the zircons were still youthful enough at 100 my old to resist attack by fluids.

We also note that if Sr was lost from these rocks at 418 my, when they were only about 100 my old, only a modest amount of radiogenic ^{87}Sr could have been lost from each sample, since only a modest amount would have accumulated by that time. Hence the resultant scatter of data on an isochron diagram would be roughly restricted to a field ranging between the true age and the resetting age of the rocks. This may account for the limited, though significant, nature of scatter in our scatterchrons.

If the gabbro hornblendes did indeed resist K-Ar resetting, then this may indicate that they were impervious to the fluids which entered the syenites and granites at 418 my. The syenites and granites may have been more highly fractured than the gabbros at this time. If so, fluids may have had access to virtually every mineral in these plutons.

The temperature of the resetting fluid is still under investigation; laboratory studies on isotopic exchange in feldspars by O'Neil and Taylor (1967) suggest that it need not have been high. Wenner and Taylor (1976), working in the St. Francois Mountains of Missouri, argued for Precambrian low-temperature (ca. 100°C) alteration of shallowly emplaced 1500 my granitic rocks. This alteration is suspected of implanting hematitic inclusions in K-feldspar, and also of possibly producing disruptions in the Rb-Sr systematics. In fact, the similarities between the St. Francois Mountains and the Florida Mountains are striking: (1) both show evidence of shallow emplacement of plutons, including porphyritic texture; (2) both contain abundant turbid, brick-red K-feldspars with minute hematitic inclusions, characteristic of red-rock granophyres known from the Precambrian; (3) both show scattered Rb-Sr dates which are systematically younger than the U-Pb dates; and (4) in both cases, evidence is lacking for a major metamorphism at the appropriate time, and a low-temperature fluid seems likely. A basically similar mechanism is probably required to explain both occurrences. It may be important to note, however, that virtually all other red-rock granophyres are Precambrian, while the Florida Mountains may represent a rare Paleozoic example.

The ages from the Florida Mountains also pose interesting possibilities for mid-Paleozoic plate boundary conditions, and the tectonic framework of the southern Cordillera. Brookins (1980) notes that the presence of lower to middle Paleozoic plutonism supports the idea of Loring and Armstrong (1980) for a southward extension of Paleozoic plutonism noted in Colorado and northern New Mexico; he also notes the possibility that the Florida Mountains plutonism is a westward extension of the Texas lineament. Dates near 500 my are noted in the Ouachitas and elsewhere to the east, and it is tempting to postulate extending "Grenville to Avalonian" tectonic features into the Florida Mountains, which, in turn, could imply that the plate boundary for the area in early to middle Paleozoic time was far north of where it is commonly drawn. This avenue of research is being pursued by the authors at the present time.

CONCLUSIONS

The conclusions we reach from our evaluation of the available geochronologic data for the Florida Mountains are as follows:

1. Lower Paleozoic plutonism in the area is confirmed by the U-Pb concordia age of 514 ± 3 my for five zircons separated from alkali granite. This date agrees with the ages of 495 to 523 my reported by Evans and Clemons (1987).
2. Definite Precambrian gneisses occur in the area; Evans and Clemons (1987) report ages of 1.55 to 1.57 by for zircons.
3. K-Ar ages from syenites yield two groups: one at 418–419 my and one at 530–555 my (Brookins, 1974). The latter ages may be formational, although this then raises questions about the U-Pb ages. The 418–419 my ages must have been reset, probably at about this time.
4. K-Ar ages from a monzonite dike and an andesite dike are 61.5 my 27.9 my respectively; these are tentatively interpreted in this report as due to periods of mineralization.
5. Rb-Sr dates from the syenites and alkali granites of the core igneous rocks yield scatterchrons in the general range 380–450 my. Data from Matheney (1984) show evidence for mobilization of both U and Fe in many samples, and it is likely that Rb-Sr systematics have been perturbed as well. Herein we advocate possible loss of Sr from the rocks, as this best explains lowering of both isochron ages and initial ratios.
6. The resetting event affecting the syenites and alkali granites also affected the arkosic rocks of the Bliss(?) Formation, as possible isochron ages are 380 and 283 my for this Cambro-Ordovician unit.
7. Possible mineral Rb-Sr isochrons exhibit wide scatter (Matheney, 1984), ranging from 283 ± 106 to 566 ± 26 my. The scatter is offered as evidence that these rocks have had their Rb-Sr systematics perturbed.
8. The Florida Mountains igneous core rocks may be an extension of the Texas lineament, although much more work is needed to test this idea.

ACKNOWLEDGMENTS

R. K. Matheney's field studies for this research were supported by a grant-in-aid of research from Sigma Xi, the Scientific Research Society, and by a research grant from the Student Research Allocations Committee of the University of New Mexico's Graduate Student Association. Dr. W. R. Van Schmus, University of Kansas, kindly allowed E. T. Wallin to analyze Florida Mountain zircons in his U-Pb analytical laboratory. Part of the research of the University of Arizona (Damon, Shafiqullah) was supported by the Marathon Oil Company. We have benefited from conversations with Russ Clemons (NM State University), Frank Kottlowski (NM Bureau of Mines), Karl Evans (USGS) and Tim Dennison (Mobil; consultant).

REFERENCES

Brookins, D. G., 1974, Radiometric age determinations from the Florida Mountains, New Mexico: Geology, v. 2, p. 555–557.

Brookins, D. G., 1980, Paleozoic plutonism from southern New Mexico: evidence form the Florida Mountains: Geophysical Research Letters, v. 7, p. 741–744.

Brookins, D. G., Rautman, C. A. and Corbitt, L. L., 1978, Uranium and thorium abundances and whole rock chemistry of the Florida Mountains, New Mexico: preliminary report: University of New Mexico Energy Institute, Report 77-1104-3, 23 p.

Brooks, C., Hart, S. R. and Wendt, I., 1972, Realistic use of two-error regression treatments as applied to rubidium-strontium data: Review of Geophysics and Space Physics, v. 10, p. 551–557.

Clemons, R. E., 1982, Petrography and age of plutonic rocks of Florida Mountains, New Mexico—preliminary report: New Mexico Geology, v. 4, p. 33–38.

Clemons, R. E., 1984, Geology of Capitol Dome quadrangle, Luna County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 56.

Clemons, R. E., 1985, Geology of South Peak quadrangle, Luna County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 59.

Clemons, R. E. and Brown, G. A., 1983, Geology of Gym Peak quadrangle, Luna County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 58.

Corbitt, L. L., 1971, Structure and stratigraphy of the Florida Mountains, New Mexico [Ph.D. dissertation]: Albuquerque, University of New Mexico, 115 p.

Corbitt, L. L. and Woodward, L. A., 1973, Tectonic framework of the Cordilleran foldbelt in southwestern New Mexico: American Association of Petroleum Geologists Bulletin, v. 57, p. 2207–2216.

Evans, K. V. and Clemons, R. E., 1987, U-Pb geochronology of the Florida Mountains, New Mexico: new evidence for latest Cambrian-earliest Ordovician alkali plutonism: Geological Society of America, Abstracts with Programs, v. 19, p. 657–658.

Faure, G., 1986, Principles of isotope geology (2d ed.): New York, John Wiley & Sons, 560 p.

Faure, G. and Powell, J. L., 1972, Strontium isotope geology: New York, Springer-Verlag, 188 p.

Lemone, D. V., 1974, The Lower Ordovician Florida Mountains stratotype, Luna County, New Mexico; *in* Corbitt, L. L., ed., Geology of the Florida Mountains, Luna County, New Mexico: El Paso Geological Society, Guidebook 8, p. 36–46.

Lochman-Balk, C., 1958, The Capitol Dome section, Florida Mountains: Roswell Geological Society Guidebook, Hatchet Mountains and Cooke's Range—Florida Mountains Area, p. 47–52.

Loring, A. K. and Armstrong, D. G., 1980, Cambrian-Ordovician syenites in New Mexico: Geology, v. 8, p. 344–348.

Matheney, R. K., 1984, Rb-Sr geochronologic studies of plutonic rocks, Florida Mountains, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 141 p.

O'Neil, J. R. and Taylor, H. P., Jr., 1967, The oxygen and cation exchange chemistry of feldspars: American Mineralogist, v. 52, p. 1414–1437.

Taylor, H. P., Jr., 1967, Origin of red-rock granophyres: Transactions of the American Geophysical Union, v. 48, p. 245–246.

Wenner, D. B. and Taylor, H. P., Jr., 1976, Oxygen and hydrogen isotope studies of a Precambrian granite-rhyolite terrane, St. Francois Mountains, southeastern Missouri: Geological Society of America Bulletin, v. 87, p. 1587–1598.

Old Hachita and Howell's Ridge, Little Hatchet Mountains. View is S5°W. Ruined adobe residences are about 0.8 km southeast of main Old Hachita townsite. Low hills in left middle distance are Hell-to-Finish Formation capped by U-Bar Formation. Low area between hills and Howell's Ridge (upper right) is underlain by Hidalgo Volcanics and Tertiary quartz monzonite. Howell's Ridge is capped by massive, reef limestone member of U-Bar thrust over slope-forming Hell-to-Finish. Area around adobe ruins covered by gravel veneer on altered U-Bar, Hell-to-Finish and Tertiary intrusive rocks. Creosote is the dominant shrub in the foreground. Juniper trees are scattered on the slopes and crest of Howell's Ridge. Big Hatchet Mountains in distance at left. Camera station is in NE1/4 SE1/4, sec. 36, T27S, R6W. Altitude about 1486 m. W. Lambert photograph No. 87L39. 24 July 1987, 12:12 p.m., MDT.