GSA Data Repository Item # 8529

Title of article Petrologic, paleomagnetic , and structural evidence of a Paleozoic rift system in Oklahoma, New Mexico, Colorado, and Utah"

Author(s) E. E. Larson, P. E. Patterson, G. Curtis, R. Drake, and F. E. Mutschler

see Bulletin v. 96, p. 1364 - 1372

Contents 12 pages

Appendix 1 and 2 and Tables 1 through 6

APPENDIX 1

Collection and Laboratory Procedures

Three to six oriented hand samples were taken from each dike; orientations were obtained with Brunton and sun compasses. We included in our selection the sole dike that trends NNE (No. 7), and two of the dikes that cut the Precambrian outlier along the southern rim of the late Miocene Lake City caldera (Nos. 13, 14). In choosing sampling sites we kept several ideas in mind. First, to provide a regional representation and to minimize the possibility of obtaining samples from a single, structurally deformed zone, we selected dikes over a broad area. Secondly, we tried to select sites in the bottoms of canyons, far removed from ancient and modern-day weathering surfaces. Thirdly, we were careful at each site to take only the freshest-appearing samples.

Polished thin sections were made from samples from all sites for use in transmitted- and reflected-light petrographic studies. Electron-microprobe analysis on selected thin sections was done on a MAC probe at the University of Colorado. After preliminary petrographic examination, we chose fresh samples from four of the dikes for whole-rock K-Ar dating. One of the freshest samples (from the thickest dike, No. 4) was also used in determination of a mineral-separate Rb-Sr isochron. K-Ar and Rb-Sr dating was done at the University of California, Berkeley and the U.S. Geological Survey, Denver, respectively.

Samples from nine of the dikes were chemically analyzed. Paleomagnetic and rock magnetic analyses were performed at the University of Colorado.

APPENDIX 1 (con't)

Site Locations

Dike	Location
1	Cliffside below rim; SW 1/4 sec 32, T50N, R7W
2	Roadside outcrop; NW 1/4 sec 10, T48N, R7W
3	On ridge below road; NW 1/4, sec 33, T49N, R6W
4	Roadside outcrop along the Lake Fork of the Gunnison River; SE 1/4 sec 8, T47N, R3W
5	Cliffside above road; center sec 32, T48N, R3W
6	Hillside outcrop; NE 1/4 sec 32, T47N, R2W
7	Hillside outcrop; NE 1/4 sec 5, T48N, R2W
8	Hillside outcrop; 100 m above road; NE 1/4 sec 32, T48N, R3W
9	Canyon mouth outcrop, Unaweap Canyon; SW 1/4 sec 11, T14S, R100W
10	Stream bottom outcrop, Unaweap Canyon; NW 1/4 sec 15, T14S, R100W
11	Creek bottom outcrop; SE 1/4 sec 2, T46N, R2W
12	Creek bottom outcrop; NE 1/4 sec 5, T48N, R1W
13	Roadside outcrop; Lat. 37° 54.4', Long. 107° 25.4'
14	Roadside outcrop; Lat. 37° 54.1', Long. 107° 26.2'

APPENDIX 2

Cambrian Paleopoles Given in Figure 7

Pole No.	Description
1	Southwestern Colorado Diabase Dike Swarm - 497 ± 16 m.y.—This study.
2	Abrigo Formation - Middle and Late Cambrian - Elston and Bressler, 1977.
3	Muav Limestone - Middle Cambrian - Elston and Bressler, 1977.
4	Sawatch Sandstone - Late Cambrian - Howell and Martinez, 1957.
6	Rome Formation - Middle Cambrian - Watts and others, 1980b.
5	Colorado Intrusives, Group III - Late Precambrian to Early Paleozoic - French, and others, 1977.
7	Wichita Granite (a.f. direction) 525 m.y. - Ku, and others, 1967.
8	Bradore Formation - Early Cambrian - Rao and Deutsch, 1976.
9	Lamotte Formation (Groups 1 and 2, 378°C. demagnetization) - Late Cambrian - Al-Khafaji and Vincenz, 1971.
10	Colorado Intrusives, Group I - Late Precambrian to Early Paleozoic - French and others, 1977.
11	New Foundland Ophiolitic Complex - Cambrian - Sequin, 1976.
12	Wichita Mountain Granites - 525 m.y. - Spall, 1970.
13	Tapeats Sandstone - Early and Middle Cambrian - Elston and Bressler, 1977.
14	Wilberns Formation - Late Cambrian - Van der Voo, and others, 1977.
15	Wichita Mountain Granites (500° C. demagnetization) - 525 m.y. - Spall, 1970.
16	Colorado Intrusives, Group II - Late Precambrian to Early Paleozoic - French, and others, 1977.
17	Lamotte Formation (Group 2 only, 378° C. demagnetization) - Late Cambrian-Al-Khafaji and Vincenz, 1971.

4. 8/12.

18 Lamotte Formation (Groups 2a, 2b, a.f. demagnetization) - Late Cambrian - Al-Khafaji and Vincenz, 1971.

19 Waynesboro Formation - Early to Early Middle Cambrian - Watts and others, 1980b.

20 Cloud Mountain Basalt - latest Precambrian (605 ± 10 m.y.) - Deutsch and Rao, 1977.

21 Average of Franklin Lavas and Dikes - Late Precambrian (675 - 625 m.y.) - Palmer and Hayatsu, 1975.

22 Point Peak Member, Wilbersn Formation - 507 m.y. - Watts and others, 1980a.

23 Mean of Hickory, Cap Mountain, Lion Mountain, and Morgan Creek - Welge Members, Riley and Wilberns Formations - Late Cambrian - Watts and others, 1980a.

24 Mean of Groups I and II, Carmara and Bonanza King Formations - Middle Cambrian - Gillett and Van Alstine, 1979.

25 Wood Canyon Formation - Early Cambrian - Gillett and Van Alstine, 1979.

26 Nolichucky Formation, Site I - Late Cambrian - Gillett, 1982.

27 Nolichucky Formation, Site II - Late Cambrian - Gillett, 1982.

28 Orr Formation - Late Cambrian - Gillett, 1982.

References

Al-Khafaji, S. A. and Vincenz, S. A., 1971, Magnetization of the Cambrian Lamotte Formation in Missouri: Geophysical Journal Royal Straonomical Society, v. 24, p. 175.

Deutsch, E. R., and Rao, K. V., 1977, New paleomagnetic evidence fails to support rotation of western Newfoundland: Nature, v. 266, p. 314-318.

Elston, D. P., and Bressler, S. L., 1977, Paleomagnetic poles and polarity zonation from Cambrian and Devonian strata of Arizona: Earth and Planetary Science Letters, v. 36, 423-433.

French, R. B., Alexander, D. H. and Van derVoo, R., 1977, Paleomagnetism of upper Precambrian to lower Paleozoic intrusive rocks from Colorado: Geological Society America Bulletin, v. 88, no. 12, p. 1785-1792.

Gillett, S. L., 1982, Paleomagnetism of the Late Cambrian _Crepicephalus-Aphelaspis_ trilobite zone boundary in North America--divergent poles from isochronous strata: Earth and Planetary Science Letters, v. 58, p. 383-384.

Gillett, S. L., and Van Alstine, D. R., 1979, Paleomagnetism of the Lower and Middle Cambrian sedimentary rocks from the Desert Range, Nevada: Journal of Geophysical Research, v. 84, p. 4475-4489.

Howell, L. G., and Martinez, J. D., 1957, Polar movement as indicated by rock magnetism: Geophysics, v. 22, p. 384-397.

Ku, C. C., Sun, S., Soffel, H. and Sharon, L., 1967, Paleomagnetism of the basement rocks, Wichita Mts., Oklahoma: Journal of Geophysical Research, v. 72, p. 731.

Palmer, H. C., and Hayatsu, A., 1975, Paleomagnetism and K-Ar dating of some Franklin lavas and diabases, Victoria Island: Canadian Journal of Earth Sciences, v. 12, p. 1439-1477.

Roa, K. V. and Deutsch, E. R., 1976, Paleomagnetism of the Lower Cambrian Bradore sandstones and the rotation of Newfoundland: Tectonophysics, v. 33, No. 34, p. 337.

Sequin, M. K., 1976, Reconnaissance paleomagnetic investigation of the ophiolitic complex Thetford Mines Asbestos, Quebec: Tectonophysics, v. 34, No. 3-4, p. 231.

Spall, H., 1970, Paleomagnetism of basement granites in Southern Oklahoma; Final Report: Oklahoma Geology Notes, v. 30, p. 136.

Van der Voo, R., French, R. B. and Williams, D. W. 1977, Paleomagnetism of the Wilbers Formation (Texas) and the Late Cambrian paleomagnetic field for North America: Journal of Geophysical Research, v. 81, p. 5633.

Watts, D. R., and Van der Voo, R., 1980, Cambrian paleomagnetism of the Llano Uplift, Texas: Journal of Geophysical Research, v. 85, p. 5316-5330.

Watts, D. R., Van der Voo, R., and French, R. B.,1980, Paleomagnetic investigation of the Cambrian Waynesboro and Rome Formations of the Valley and Ridge Province of the Appalachian Mountains: Journal of Geophysical Research, v. 85, p.5331-5343.

TABLE 1

Mean Modal Analysis (2 samples each from 5 dikes)

Mineral	Volume Percent
Plagioclase	47.3
Clinopyroxene	28.7
Quartz - alkali feldspar intergrowths	15.2
Iron-titanium oxides	4.3
Hornblende	2.3
Biotite	2.2
Apatite	trace

TABLE 2

Microprobe analyses of minerals from diabase dikes

(Values are weight percent)

	Clinopyroxene (11 samples)	Hornblende (5 samples)	Biotite (4 samples)
SiO_2	51.9	45.8	36.8
Al_2O_3	2.0	6.1	12.9
FeO	14.0	25.5	27.3
MgO	14.6	5.9	8.1
CaO	16.8	10.7	-
Na_2O	-	1.3	-
K_2O	-	0.8	7.9
TiO_2	0.7	1.2	-
MnO	-	0.3	-
Cl	-	0.3	0.4

TABLE 3

CHEMICAL ANALYSES OF DIABASE DIKES
Major Oxides (Weight percent)

Dike	1	3	4	5	6	7+	8	9	10	Qtgab*	Diab.**	Avg.***
SiO_2	53.46	53.36	53.42	50.98	52.68	50.82	51.84	50.80	53.24	52.20	52.80	52.48
Al_2O_3	13.40	14.00	13.80	13.20	13.00	16.40	13.00	12.80	12.80	14.70	14.50	13.52
Fe_2O_3	1.60	2.00	2.00	3.80	3.80	2.50	3.30	3.70	1.20	1.50	2.80	2.57
FeO	10.3	9.90	9.70	9.90	8.10	8.30	9.60	10.70	10.20	9.90	9.10	9.74
MgO	4.80	4.30	5.00	4.30	4.80	6.50	4.60	4.60	4.80	5.40	4.60	4.72
CaO	8.50	8.00	8.40	8.20	8.00	8.30	7.60	8.20	8.50	8.80	8.80	8.30
Na_2O	2.30	2.40	2.40	2.30	3.80	2.60	2.70	2.20	2.30	2.70	2.70	2.58
K_2O	1.00	1.20	1.00	1.10	0.55	0.90	1.30	1.20	1.00	1.30	0.97	1.06
TiO_2	2.30	2.50	2.20	3.00	2.20	1.10	2.80	3.20	2.30	1.54	1.95	2.40
P_2O_5	0.10	0.10	0.15	0.25	0.15	0.07	0.15	0.25	0.15	0.25	0.27	0.18
MnO	0.20	0.19	0.20	0.21	0.19	0.18	0.21	0.23	0.20	-	0.22	0.21
CO_2	0.20	0.05	0.05	0.20	0.05	0.05	0.05	0.05	0.20	-	0.05	0.10
Total	98.16	98.00	98.32	97.44	97.32	97.72	97.15	97.93	96.89	98.29	98.76	
Trace Elements (ppm)												
Rb	-	39	32	-	-	-	61	45	17	-	-	39
Sr	-	333	335	-	-	-	315	405	616	-	-	400
V	-	2368	4930	-	-	-	4400	1814	2170	-	-	3136
Normative Minerals												
Q	11.43	11.56	10.56	10.01	5.67	2.28	8.72	9.55	12.02	4.45	6.98	
Or	5.91	7.09	5.91	6.50	3.25	5.32	7.68	7.09	5.91	7.80	5.70	
Ab	19.45	20.30	20.30	19.45	32.14	21.99	22.84	18.61	19.45	23.20	22.85	
An	23.29	23.88	23.93	22.45	16.79	30.42	19.52	21.51	21.65	24.53	24.60	
Di-Wo	7.08	5.80	6.47	6.40	8.62	3.77	6.65	6.79	7.63	7.58	7.10	
Di-En	3.94	3.22	3.65	3.41	4.79	2.12	3.73	3.64	4.39	4.10	3.47	
Di-Fs	2.89	2.34	2.55	2.79	3.49	1.50	2.66	2.94	2.89	3.22	3.51	
Mt	5.51	5.80	5.37	6.53	5.37	3.77	6.24	6.82	5.51	4.48	4.06	
Il	4.37	4.75	4.18	5.70	4.18	2.09	5.32	6.08	4.37	2.97	3.70	
Ap	0.24	0.24	0.36	0.59	0.36	0.17	0.36	0.59	0.36	0.60	0.63	
Cc	0.46	0.50	0.50	0.50	0.46	0.46	0.46	0.46	0.46	-	0.11	
Hy-En	8.01	7.48	8.80	7.29	7.16	14.07	7.73	7.82	7.56	9.56	7.99	
Hy-Fs	5.84	5.44	6.14	5.95	5.21	9.95	5.53	6.32	4.98	7.52	8.07	

* Quartz gabbro dike, Powderhorn. Analysis from Larsen (1942)

** Diabase dike, Black Canyon. Unpublished analysis from W. R. Hansen, U.S.G.S.

*** Excluding Dike #7.

\+ Analysis from the NNE-trending dike

Major oxides analyses by XRF and AA. Skyline Laboratories, Littleton, Colorado

Trace element analyses by semiquantitative XRF. U.S. Geological Survey Isotope

TABLE 4

Rb-Sr Radiometric Data, Dike 4

Material	Rb,ppm	Sr,ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Potassium-feldspar concentrate	118.8	179.4	1.919	0.7189_6
Plagioclase separate	14.4	480.0	0.087	0.7062_0
Pyroxene separate	11.3	131.4	0.250	0.7069_4

Regressions (decay constant = 1.42×10^{-11} yr^{-1})

MSWD 5.6 Initial ratio 0.7052 ± 0.0002

Age = 495 ± 15 m.y.

Analyst: K. Futa

TABLE 5

K-Ar Radiometric Data*

Dike	% K	mol/gm ^{40}Ar rad. $x10^{-11}$	% ^{40}Ar Atmos.	Age m.y.
3	1.708	115.860	4.0	533 ± 20
4	.966	143.900	9.0	704 ± 23
5	1.031	103.930	13.0	504 ± 16
10	.9405	70.864	4.3	390 ± 16

*Constants: $^{40}K/K = 1.167 \times 10^{-4}$ mol/mol; $\lambda_\beta = 4.962 \times 10^{-10}$ yr^{-1};

$\lambda_\varepsilon + \lambda'_\varepsilon = 0.581 \times 10^{-10}$ yr^{-1}.

TABLE 6

Best-grouped Paleomagnetic Data for Nine Dikes

			Structurally Uncorrected		Structurally Corrected			
Dike	No. of Samples	Demag Step[1]	Mean Dec[2]	Mean Inc[3]	Mean Dec[2]	Mean Inc[3]	Precis Param, k[4]	Alpha 95[5]
1	5	20-mT	152.3	37.5	150.1	40.4	44.3	11.6
1	5	500-C	157.9	19.1	157.0	22.3	104.8	7.5
2	3	5-mT	160.9	32.8	159.7	35.3	26.4	24.5
2	3	500-C	172.0	17.9	171.6	20.7	66.7	15.2
3	7	10-mT	153.9	3.4	153.7	5.7	138.7	5.1
3	7	400-C	150.6	11.3	150.1	13.4	81.4	6.7
4	6	10-mT	153.5	20.2	154.1	17.8	27.3	13.1
4	6	500-C	165.8	33.0	166.5	30.3	50.5	9.5
6	3	15-mT	-176.6	35.6	-176.6	35.6	6.8	51.5
6	4	400-C	156.0	35.8	156.0	35.8	11.2	28.8
9	5	20-mT	154.2	-31.8	158.1	-31.8	26.7	15.1
9	5	400-C	151.9	6.5	151.6	6.3	17.0	19.1
10	6	20-mT	154.1	18.8	153.1	18.7	4.4	36.0
10	6	400-C	151.1	-1.1	151.2	-1.3	216.9	5.2
11	6	20-mT	144.8	15.8	144.8	15.8	13.9	18.6
11	6	400-C	144.2	21.9	144.2	21.9	37.2	11.1
12	5	10-mT	-17.4	-27.3	-18.0	-30.1	7.8	29.3
12	5	400-C	-19.3	-15.5	-19.7	-18.2	40.8	12.1

1 Given a.f. or thermal demagnetizati represents that at which minimum scatterof the sample remanence was exhibited, based on maximum values of the precision parameter

2 Mean declination

3 Mean inclination

4 Fisher precision parameter

5 Radius of Fisher 95%-cone of confidence about mean

TABLE 7

Composite Mean Directions and Paleopoles

A. F. Demagnetization

	Mean Dec	Mean Inc	k	Alpha 95	Paleo-lat	Paleo-long	Delta p	Delta m
Struct. uncorr.	157.3	18.6	12.3	15.3	37.5N	101.2E	8.3	15.9
Struct. corr.	157.2	19.5	11.8	15.7	37.0N	101.0E	8.6	16.4

Thermal Demagnetization

	Mean Dec	Mean Inc	k	Alpha 95	Paleo-lat	Paleo-long	Delta p	Delta m
Struct. Uncorr.	156.5	17.9	32.5	9.2	37.5N	102.1E	4.9	9.5
Struct. Corr.	156.3	18.8	34.0	9.0	37.0N	102.3E	4.9	9.4