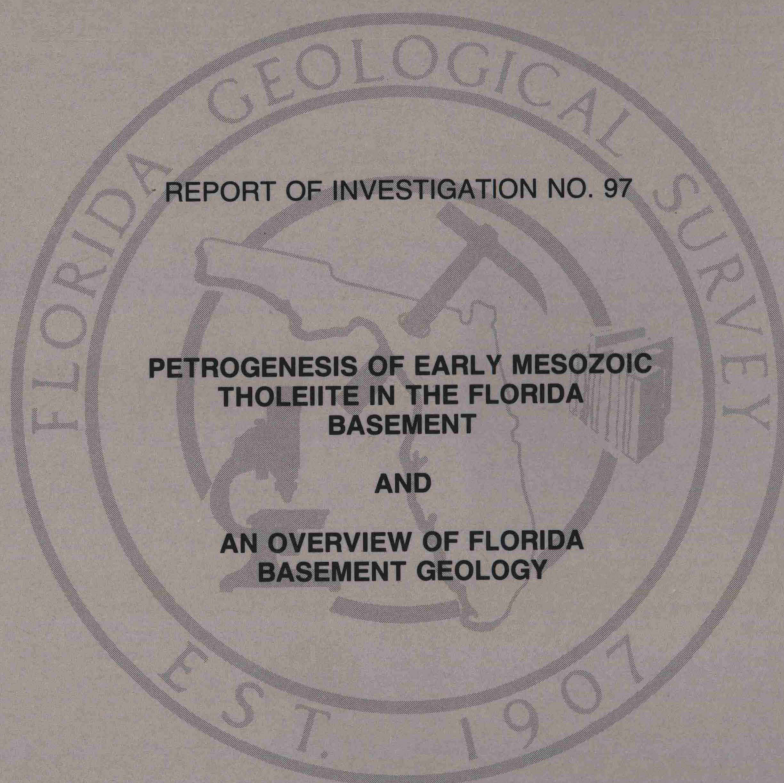


STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist*



REPORT OF INVESTIGATION NO. 97

**PETROGENESIS OF EARLY MESOZOIC
THOLEIITE IN THE FLORIDA
BASEMENT**

AND

**AN OVERVIEW OF FLORIDA
BASEMENT GEOLOGY**

By
Jonathan D. Arthur

Published for the
FLORIDA GEOLOGICAL SURVEY
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LETTER OF TRANSMITTAL

Florida Geological Survey
Tallahassee

August 1988

Governor Bob Martinez, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32301

Dear Governor Martinez:

The Florida Geological Survey, Division of Resource Management, Department of Natural Resources, is publishing a two-part study as Report of Investigation 97. Part I - "Petrogenesis of Early Mesozoic Tholeiite in the Florida Basement" interprets the origin of mafic basement rocks and discusses chemical affinities with similar rocks in the circum-Atlantic region. This information provides further insight into the geologic history of Florida.

Part II - "An overview of Florida basement geology" summarizes the lithologic and tectonic nature of the Florida basement. As such, this section provides useful information to scientists studying the deep geologic strata of Florida.

Respectfully yours,

Walter Schmidt
State Geologist and Chief
Florida Geological Survey

Printed for the
Florida Geological Survey
Tallahassee
1988

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ABSTRACT

Thirty-nine deep oil test wells have encountered diabase or basalt in the Florida basement. These mafic igneous rocks were emplaced prior to the onset of Atlantic sea-floor spreading during the Early Mesozoic break-up of Pangea. Fourteen samples from eight cores passed a petrographic screen and were analyzed by atomic absorption and x-ray fluorescence spectrometry for major- and trace-element concentrations. Minerology of samples was determined by petrographic analysis and x-ray diffraction. This study interprets the petrogenesis of the Florida tholeiitic magma and its relationship to other circum-Atlantic tholeiites emplaced during the Early Mesozoic. Also included in this report is an overview of Florida basement geology and a presentation of unpublished radiometric data on file at the Florida Geological Survey.

With one exception, all samples are quartz-normative tholeiites with mafic index values ranging from 61 to 87. A linear differentiation trend from a low-Ti and high-Fe magma type is observed for the Florida data. This pattern is similar to other eastern North American (ENA) tholeiitic suites; however, the Florida magmas are more differentiated. Petrogenetic modelling suggests that 70 to 75 percent accumulation of a fractionation assemblage consisting of 46 percent plagioclase, 45 percent clinopyroxene, 6 to 7 percent olivine and 1.5 to 2 percent Fe-Ti oxides may have produced the observed chemical variations. Phenocrysts of plagioclase, clinopyroxene and olivine observed in the samples are consistent with this model. Chemical data suggest a genetic relationship between Florida, Georgia and other ENA tholeiites. These data also suggest that the Florida and Liberia tholeiites may have had the same parental magma or different magmas of the same major element composition. No such relationship exists between Florida and either the Surinam or Morocco diabase suites.

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I express sincere gratitude to Dr. Paul Ragland for his guidance throughout the course of this study as well as his critical review of the manuscript. I am also thankful for the critical reviews of Part One of this study by Dr. Laura Cummins, Dr. David Whittington and Steven Campbell. Dr. Barry Cohn (Standard Oil) and Dr. Roy Odom were helpful in providing geochronologic data for this study.

As the basement geology section expanded from two paragraphs into Part Two of this report, I am very thankful for the encouragement, patience and input from Dr. Thomas Scott and Dr. Walt Schmidt. I am also very grateful for the critical review of Part Two by Dr. Jim Tull, which along with fruitful discussions on Florida basement geology with Paulette Bond, Jackie Lloyd and George Winston (Petroconsultants, Ltd.), led to a more comprehensive and meaningful manuscript.

David Allison is thanked for developing and providing computer graphics software used in this study as well as his technical assistance in customizing and running the programs. Special thanks are extended to Jim Jones, Ted Kiper and Melissa Doyle for preparing figures for this study and the associated Geological Society of America presentation (Arthur, et al., 1988), and to Cindy Collier for typing the manuscript.

Finally, I gratefully acknowledge those staff members of the Florida Geological Survey who reviewed the manuscript: Ms. Paulette Bond, Mr. Ken Campbell, Dr. Ron Hoenstine, Mr. Ed Lane, Ms. Alison Lewis, Ms. Jacqueline Lloyd, Ms. Joan Ragland, Mr. Frank Rupert, Dr. Walt Schmidt, Dr. Thomas Scott, Mr. Steve Spencer and Mr. Bill Yon. A cooperative agreement between the Florida Geological Survey and the Department of Geology at Florida State University enabled all of the analytical work for this study to be completed quickly, efficiently and cost-effectively. Loss on ignition analyses were completed by Don Harris.

**PETROGENESIS OF EARLY MESOZOIC THOLEIITE
IN THE FLORIDA BASEMENT
AND
AN OVERVIEW OF FLORIDA BASEMENT GEOLOGY**

By
Jonathan D. Arthur

INTRODUCTION

Basalts are extrusive igneous rocks characteristically associated with major tectonic events such as intraplate or "hot spot" volcanism, plate subduction, sea-floor spreading and continental rifting. Diabase (or dolerite), an intrusive chemical equivalent of basalt, is primarily associated with rifting events. In eastern North America (ENA), diabase is exposed within the Appalachian orogen from Alabama to Newfoundland as sheets (e.g., sills and lopoliths) and subparallel dikes. The sills, as well as associated basalt flows, crop out within a series of Mesozoic basins that parallel the Appalachian orogen. Geophysical and corehole data reveal the presence of diabase sills beneath the ENA Coastal Plain province (Gottfried et al., 1983; Chowns and Williams, 1983). Numerous studies have suggested that the ENA diabase-basalt suite is genetically related to Early Mesozoic rifting of the Pangean supercontinent (King, 1961; May, 1971; DeBoer and Snider, 1979). In Florida, 39 oil test wells have encountered diabase and basalt within pre-Cretaceous sedimentary rocks. Available geochemical and mineralogical data reveal that these igneous rocks are tholeiitic in composition (see also Part I, "Classification" section). Based upon stratigraphic, geochronologic, and very limited geochemical data, Chowns and Williams (1983) have proposed that Florida tholeiite belongs to the ENA tholeiitic suite. It is possible, however, that additional magmatic systems may have been associated with Florida tholeiite genesis due to the continental plate configuration immediately prior to the rifting event. Plate reconstructions (Bullard et al., 1965; Van der Voo et al., 1976), lithologic similarities (Smith, 1982) and isotopic data (Odom and Brown, 1976; Dallmeyer et al., 1987) suggest that northwest Africa, northeast South America and southeast North America were juxtaposed during the Early Mesozoic.

Part I of this study provides new geochemical data in order to determine the petrogenesis of Florida tholeiitic magma(s). Furthermore, this study will investigate the possibility of a genetic relationship between Florida and Georgia magmas and those magmas represented by tholeiitic dike systems of Africa and South America which were emplaced during the break-up of Pangea. Existence of such a relationship would further support theories regarding the Early Mesozoic rifting event and provide further insight into the geochemical nature of tholeiite prior to generation of mid-Atlantic ridge transform and ocean-floor basalts.

Part Two of this report summarizes Florida basement geology. Included in this section is a presentation of nomenclature currently recognized by the Florida Geological Survey as well as unpublished radiometric data on file at the Survey.

Metric Conversion Factors

The Florida Geological Survey, in order to prevent duplication of parenthetical conversion units, inserts a tabular listing of conversion factors to obtain metric units.

Multiply	By	To Obtain
feet	0.3048	meters
miles	1.6090	kilometers
inches	25.40	millimeters

**PART I - PETROGENESIS OF EARLY MESOZOIC
THOLEIITE IN THE FLORIDA
BASEMENT**

Background

AGE

A comparison of geochronological studies of Florida diabase suggests that the average age of crystallization is about 192 million years (Ma) (Milton and Grasty, 1969; Barnett, 1975; Mueller and Porch, 1983). Results of these studies are summarized in Table 1. Only those age determinations from unaltered diabase and basalt with uncertainties less than ± 15 Ma were considered for this average. Several studies have noted a lack of reproducibility in K-Ar ages for ENA diabase due to K or Ar inhomogeneity, radiogenic ^{40}Ar loss (Armstrong and Besancon, 1970) or an excess of radiogenic ^{40}Ar (Dooley and Wampler, 1983). Sutter (1985) notes that $^{40}\text{Ar}/^{39}\text{Ar}$ ages are more reproducible than K-Ar ages. For these reasons, the $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations reported by Mueller and Porch (1983) for Florida diabase (averaging 194 ± 9 Ma) may be closer to a true age of crystallization. A compilation of age determinations for diabase beneath the Coastal Plain of the southeastern United States can be found in Chowns and Williams (1983, Table 6). For diabase in the subsurface of Georgia, their tabulated

Table 1. Reported radiometric age determinations from Florida tholeiite. (WR - whole rock, MS - mineral separates)

County	Florida Geol. Survey Well Number	Depth (Ft.)	Rock Description	Method	Age (Ma)	Reference
Dixie (offshore)	Gainesville Blk. 707, #1	12,450	Altered Basalt	K-Ar WR	244 ± 10	Standard Oil, unpublished data
Franklin	W-8487	14,275	Diabase	K-Ar WR	203 ± 12 182 ± 11 186 ± 9 195 ± 12	Barnett (1975)
Franklin	W-8487	14,275	Diabase	K-Ar MS (Pyroxene)	153 ± 61 181 ± 72 129 ± 60	Barnett (1975)
Hardee	W-1655	11,853	Highly Altered Basalt	K-Ar WR	147 ± 3 143 ± 7	Milton and Grasty (1969)
Hardee	W-1655	11,870	Basalt	$^{40}\text{Ar}/^{39}\text{Ar}$ WR	192 ± 7 196 ± 6	Mueller and Porch, (1983)
Highlands	W-966	12,664	Slightly Altered Basalt	K-Ar WR	183 ± 10	Milton and Grasty (1969)
Lee	W-10566	15,708	Basalt (Composite)	K-Ar WR	$163 \pm ?$	Barnett (1975)

results yield an average crystallization age of 194 ± 11 Ma. Summarizing geochronologic investigations of ENA diabase dikes, Cummins (1987) reports that crystallization occurred between 175 and 200 Ma, probably toward the lower (older) end of this range. Emplacement of the Florida and Georgia subsurface tholeiites was apparently synchronous with that of the average ENA tholeiitic suite.

CLASSIFICATION

Early studies of ENA diabase have noted that the rocks are essentially uniform in chemistry and mineralogy (e.g., Walker, 1969). Weigand and Ragland (1970), however, in a geochemical study of diabase dikes, recognized four parental magma types based upon TiO_2 content, mafic index (MI) values [calculated as $\text{Fe}_2\text{O}_3^*/(\text{Fe}_2\text{O}_3^* + \text{MgO})$, total Fe^* as Fe_2O_3] and normative mineralogy (Table 2).

Table 2. Magma types recognized by Weigand and Ragland (1970). Abbreviations with asterisk taken from Ragland and Whittington (1983).

<u>MAGMA TYPE</u>	<u>ABBREVIATION</u>	<u>TiO₂ (WT.%)</u>	<u>MAFIC INDEX</u>
High-TiO ₂ , quartz-normative	HTQ*	> 0.9	> 57
Low-TiO ₂ , quartz-normative	LTQ*	< 0.9	> 57
High-Fe ₂ O ₃ , quartz-normative	HFQ*	> 0.9	> 74
Olivine-normative	OLN		

This fundamental classification is currently applied to all ENA tholeiitic intrusives and extrusives; however, the HFQ variety has more recently been recognized as a differentiate of the HTQ and LTQ parental magmas (Maxey, 1973; Ragland and Whittington, 1983). Puffer and Philpotts (1988) have recognized two fractionation trends that evolve toward two high-Fe "sub-type" magmas in the north-eastern United States: an incompatible element enriched (IEE) pattern that includes the average HTQ magma composition and an incompatible element depleted (IED) pattern that is equivalent to an LTQ-HFQ trend (based upon Weigand's (1970) averages). Gottfried et al. (1986) have added three new groups (or subgroups) to the Weigand and Ragland (1970) classification based upon rare earth element and Sr-isotope concentrations. These three groups are not considered in this report because the discriminating geochemical variables were not analyzed. Cummins (1987) recognized three petrographic groups for diabase dikes in Virginia. These groups included (1) olivine-spinel bearing (OSB); (2) granophyre bearing (GRB); and (3) spinel-granophyre absent (SGA).

Six whole-rock major element analyses have been reported for Florida's subsurface tholeiite (Milton and Grasty, 1969; Mueller and Porch, 1983). Normative mineralogy and chemical data for these six samples, shown in Table 3, indicate that the HTQ, LTQ, HFQ and OLN magma types are present in Florida. Although only one sample from Florida (MP-14, Table 3) belongs to the OLN group, 12 of 18 tholeiites from southern Georgia are olivine normative (Chowns and Williams, 1983).

Table 3. Major element compositions and normative mineralogy of Florida tholeiite reported by Milton and Grasty ("MG" samples; 1969) and Mueller and Porch ("MP" samples; 1983). [MI calculated as $\text{Fe}_2\text{O}_3^*/\text{Fe}_2\text{O}_3^* + \text{MgO}$, normative minerals calculated on a dry basis with $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.1$, * - Total Fe, NR - Not Reported].

Weight Percent	MG2	MG5	MG6	MP12	MP13	MP14
SiO ₂	46.8	50.9	52.8	53.65	52.87	47.08
TiO ₂	0.83	1.2	1.1	1.73	1.79	3.45
Al ₂ O ₃	17.1	16.6	15.3	13.47	12.83	18.21
Fe ₂ O ₃	3.5	4.3	2.2	NR	NR	NR
FeO	6.1	4.6	9.9	13.20*	14.00*	12.95*
MnO	0.11	0.08	0.22	NR	NR	NR
MgO	10.5	6.2	4.4	3.99	3.87	9.25
CaO	3.2	6.3	8.9	7.63	8.29	7.02
Na ₂ O	1.2	3.3	2.5	2.56	2.51	2.58
K ₂ O	3.3	0.57	0.68	1.35	1.01	0.29
P ₂ O ₅	0.12	0.17	0.17	NR	NR	NR
Volatiles	6.5	4.9	1.6	NR	NR	NR
TOTAL	99.3	99.1	99.8	97.6	97.2	100.8
MI	49.3	60.1	74.8	78.4	79.9	60.6
Rb(ppm)	NR	NR	NR	43	35	5
Sr(ppm)	NR	NR	NR	268	292	348
Weight Percent Norms						
Quartz	1.78	6.50	6.96	7.07	6.98	0
Corundum	6.40	0	0	0	0	0.78
Orthoclase	21.02	3.62	4.09	8.17	6.14	1.70
Albite	10.94	29.61	21.53	22.18	21.84	21.63
Anorthite	16.40	30.37	28.90	21.66	21.23	34.63
Diopside	0	1.27	12.31	14.14	17.57	0
Hypersthene	36.51	19.25	20.49	21.31	20.50	21.25
Olivine	0	0	0	0	0	12.24
Magnetite	5.47	6.62	3.25	2.16	2.30	2.04
Ilmenite	1.68	2.39	2.10	3.33	3.46	6.43
Apatite	0.28	0.39	0.38	----	----	----
County	St. Lucie	Taylor	Taylor	Hardee	Hardee	Highlands
Well No.	W-4323	W-1877	W-1877	W-1655	W-1655	W-966
Description	Amygdaloidal Basalt	Diabase	Diabase	Basalt	Basalt	Altered Basalt

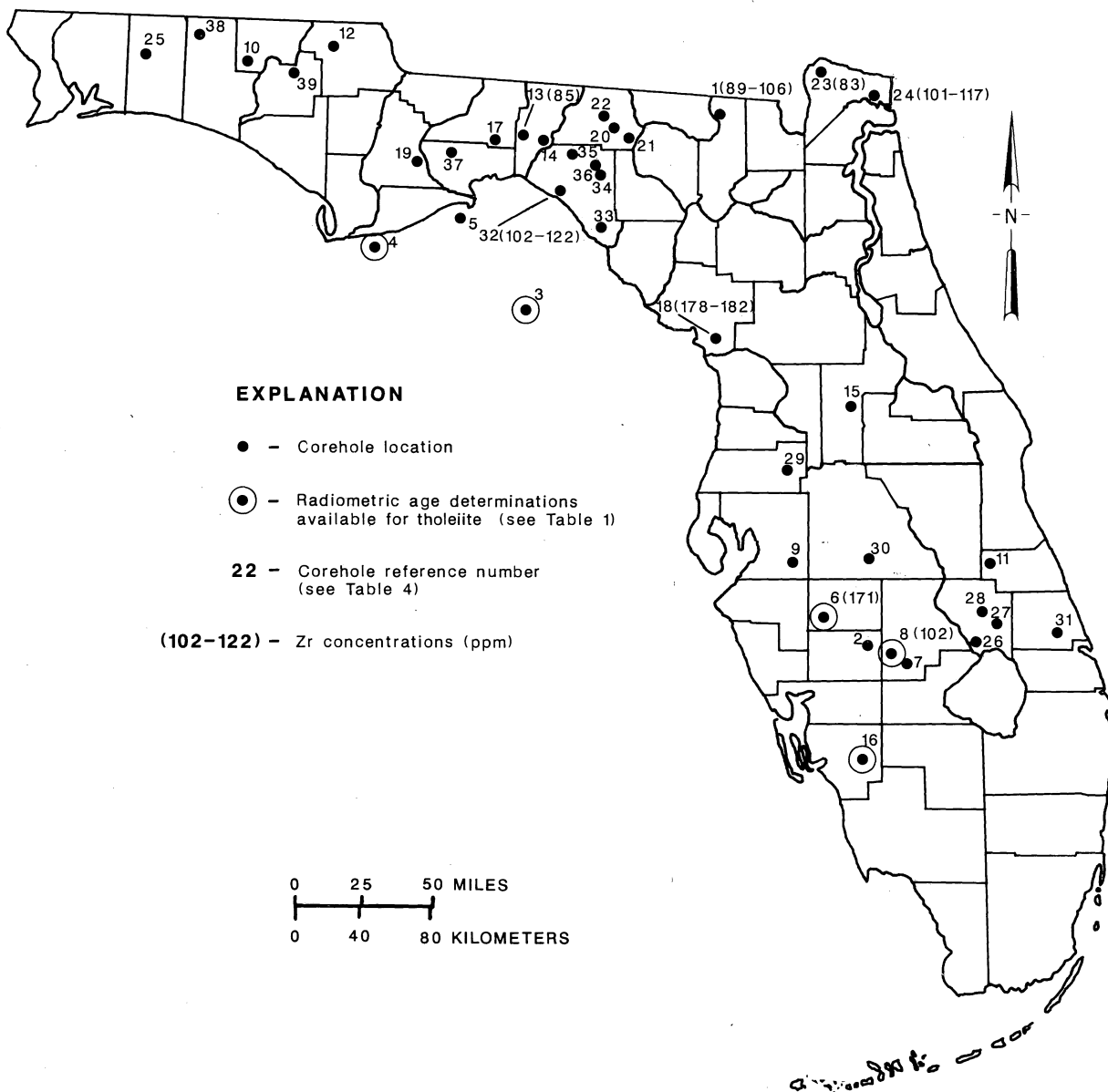


Figure 1. Oil test well locations that have encountered diabase and basalt.

DISTRIBUTION

Oil test wells in Florida that have encountered diabase or basalt are shown on Figure 1. The number adjacent to each well on Figure 1 corresponds to the left hand column on Table 4. Other information summarized in Table 4 includes specific well localities, references indicating types of data that are reported for each well and depth intervals that contain diabase or basalt.

Table 4. Florida deep wells that have penetrated diabase or basalt (modified from Lloyd, 1985, and lists only wells that have been previously described). Well locations are shown in Figure 1.

FIGURE 1 MAP LOCATION NUMBER	COUNTY	WELL NO. PERMIT NO.	WELL NAME	LOCATION	ELEV. OF WELL, FT.	TOTAL DEPTH OF WELL, FT.	¹ REFERENCE - DATA	TYPE OF THOLEIITE ENCOUNTERED	DEPTH TO THOLEIITE/ PENETRATION THICKNESS, FT.
1	Columbia	W-1789 P-77	Humble Oil & Re- fining Co.-J.P. Cone No. 1	Sec. 22 T1N, R17E	141	4444	2-1 6-1, 2 9-2, 3, 4	Diabase and amygdaloidal basalt encountered in black shale	3529/33 3564/1 4191/1 4193/2 4248/3 4267/3
2	DeSoto	W-12393 P-679	Amoco Prod. 1 - Opal Knight	Sec. 19 T36S, R27E	119	11655	7-1	Jurassic diabase	11627/28
3	Dixie (Offshore)		Sohio, Gainesville 707, #1	OCS Gainesville Block 707		12453	Standard Oil (unpub.) 1, 5	Altered basalt	12453/4
4	Franklin (Offshore)	W-8487 P-387	Mobil Prod. 1C - State Lease 224A	29°37'54"N 85°00'06"W	37	14369	6-1, 2 7-1, 2, 5	Diabase	13926/37
5	Franklin (Offshore)	W-5654 P-293	Calif. Co. and Coastal Pet. Co., No. 2	29°47'57.5"N 84°22'42.50"W		10560	6-1, 2	Diabase-basalt	10460/10 10520/10
6	Hardee	W-1655 P-62	Humble Oil & Re- fining Co. - B.T. Keen No. 1	Sec. 23 T35S, R23E	83	11934	2-1 4-2 5-2, 5 6-1, 2 8-3, 4, 5 9-2, 3, 4	Lava & pyroclastic rocks, basalt	11826/106
7	Highlands	W-966 P-B-1	Humble Oil & Re- fining Co. - C.C. Carlton Estate No. 1	Sec. 34 T38S, R29E	114	12985	2-1 5-2, 5 6-1, 2 8-3, 4	Amygdaloidal basalt, rhyolite porphyry and related volcanic rocks	12618/367
8	Highlands	W-3578 P-225	Continental Oil Co. - C.C. Carlton et al. Well No. 1	Sec. 20 T38S, R28E	88	12630	3-1 6-1, 2 9-2, 3, 4	Pre-Mesozoic? volcanic rocks	12602/28
9	Hillsborough	W-1005 P-29	Humble Oil & Re- fining Co. - T.S. Jameson No. 1	Sec. 7 T31S, R22E	112	10129	2-1 4-2 6-1, 2	Basalt	10115/10
10	Holmes	W-12199 P-716	Sonat Expl.- Randall Hughs	Sec. 32 T4N, R17W	140	11201	7-1, 2	Diabase, greenish & weathered top	10940 10940
11	Indian River	W-3783 P-243	Amerada Pet. Corp. - Fonden Mitchell Well No. 1	Sec. 28 T31S, R35E	60	9488	3-1 6-1, 2	Amygdaloidal basalt, diabase	9444/45
12	Jackson	W-1886 P-94	Humble Oil Re- fining Co. - C.W. Tindel No. 1	Sec. 8 T5N, R11W	128	9245	2-1	Triassic (?) basalt in Paleozoic strata	8890/42

Table 4. (Continued)

FIGURE 1 MAP LOCATION NUMBER	COUNTY	WELL NO. PERMIT NO.	WELL NAME	LOCATION	ELEV. OF WELL, FT.	TOTAL DEPTH OF WELL, FT.	¹ REFERENCE - DATA	TYPE OF THOLEIITE ENCOUNTERED	DEPTH TO THOLEIITE/ PENETRATION THICKNESS, FT.
13	Jefferson	W-1854 P-95	Coastal Pet. Co. -E.P. Larsh No. 1	Sec. 1 T2S, R3E	51	7913	2-1 6-1, 2 9-2, 3, 4	Triassic (?) diabase & related igneous rocks	7763/29 7850/40
14	Jefferson	W-10915 P-468	Amoco Prod. 1 - Buckeye	Sec. 17 T2S, R5E	55	7034	7-1	Diabase Gabbroic diabase Gabbroic diabase	6696/8 6730/13 6793/131
15	Lake	W-11499 P-574	Hamilton Bros. 1 - Keen	Sec. 25 T20S, R26E	92	5397	7-1	Weathered basic igneous rock	5195/202
16	Lee	W-10566 P-407	Humble 1 - Lehigh Acres	Sec. 14 T45S, R27E	57	15710	7-1, 2, 5	Altered quartz diabase	15675/35
17	Leon	W-12293 P-717	Phillips Petr. 1 - St. Joe A	Sec. 14 T2S, R1E	33	10466	7-1	Eagle Mills fm. Diabase	8450/2016 8488/68 9208/46 9316/5 9356/10 9380/2 9394/8 9430/29 10239/33
18	Levy	W-2012 P-105	Humble Oil & Re- fining Co. - C.E. Robinson No. 7	Sec. 19 T16S, R17E	58	4609	2-1 6-1, 2 9-2, 3, 4	Triassic (?) basalt	4344/33
19	Liberty	W-12496 P-730	Placid Oil 26-4 USA	Sec. 26 T3S, R5W	62	12131	7-1	Diabase	12060/10 12095/36
20	Madison	W-1596 No Permit	Hunt Oil Co. J.W. Gibson No. 2	Sec. 6 T1S, R10E	107	5385	2-1 6-1, 2	Triassic (?) diabase	4589/39
21	Madison	W-1598 No Permit	Hunt Oil Co. - J.W. Gibson No. 4	Sec. 5 T2S, R11E	73	4096	2-1	Triassic (?) diabase	4044/16
22	Madison	W-15017 P-1033	Gilman Paper Co. No. 22-2	Sec. 5 T2S, R9E	NR	10149	9-1	Altered diabase	5450/120 5800/400 9200/100
23	Nassau	W-336 No Permit	St. Marys River Oil Corp. - Hilliard Turpen- tine Co. No. 1	Sec. 19 T4N, R24E	110	4824	1-1 2-1 7-1, 2 9-2, 3, 4	Triassic (?) diabase	4808/16
24	Nassau	W-10715 No Permit	Amoco Prod. 2-1-TT Rayonier	Sec. 50 T3N, R27E	34	5469	7-1 9-2, 3, 4	Triassic diabase	5160/15 5310/15 5418/51
25	Okaloosa	W-11467 P-590	Sonat Expl. 1 - J.G. Moore 3-11	Sec. 3 T3N, R24W	170	14514	7-1	Diabase or basalt	14420/94
26	Okeechobee	W-3739 P-237	Amerada Petr. Corp. - Marie Swenson No. 1	Sec. 5 T36S, R34E	55	10838	3-1 6-1, 2	Pre-Mesozoic? volcanic rocks, basalt	10750/88
27	Okeechobee	W-12541 P-710	Shell Oil 1 - Shell Sloan 35-1	Sec. 34 T35S, R36E	60	11277	7-1	Weathered diabase	11220/57
28	Okeechobee	W-12542 P-732	Shell Oil 1 - Jean M. Davis	Sec. 9 T35S, R35	86	10767	7-1	Weathered diabase	10642/103
29	Pasco	W-12399 P-743	Amoco Prod. Co. 1 - Larkin Co. 8-4	Sec. 8 T25S, R22E	134	7148	7-1, 2	Weathered augite diabase (Jurassic)	7129/19

Table 4. (Continued)

FIGURE 1 MAP LOCATION NUMBER	COUNTY	WELL NO. PERMIT NO.	WELL NAME	LOCATION	ELEV. OF WELL, FT.	TOTAL DEPTH OF WELL, FT.	¹ REFERENCE - DATA	TYPE OF THOLEIITE ENCOUNTERED	DEPTH TO THOLEIITE/ PENETRATION THICKNESS, FT.
30	Polk	W-8741 P-403	Sun Oil 1 - Shepard Dairy	Sec. 19 T32S, R27E	169	9670	7-1, 2	Altered diabase (Jurassic)	9660/10
31	St. Lucie	W-4323 P-259	Amerada Petr. Corp. - Cowles Magazine No. 2	Sec. 19 T36S, R40E	32	12478	4-2 5-2, 3 6-1, 2	Diabase	12734/appr. 10
32	Taylor	W-1877 P-85	Humble Oil & Re- fining Co. - G.H. Hodges No. 1	Sec. 12 T5S, R6E	36	6254	2-1 5-3 6-1, 2 9-2, 3, 4	Triassic? basaltic rock Triassic? diabase gabbro	6153/12 6165/89
33	Taylor	W-2099 P-116	Gulf Oil Corp. - Brooks - Scanlon Inc., Block 42 No. 1	Sec. 9 T8S, R9E	41	5438	2-1 6-1, 2	Triassic? diabase, prob. a lava flow	5438/79
34	Taylor	W-2106 P-119	Gulf Oil Corp. - Brooks - Scanlon Inc., Block 33 No. 1	Sec. 18 T4S, R9E	96	5243	2-1	Triassic? diabase gabbro	5200/43
35	Taylor	W-10912 P-466	Amoco Prod. 1 - Canal Tbr. Co.	Sec. 12 T3S, R6E	62	7036	7-1	Diabase	6256/113 6417/247 6708/65
36	Taylor	W-15445 P-112	Amoco Prod. Buckeye Cellu. 7-4, #1	Sec. 7 T4S, R9E	111	9000	NA	Mafic igneous	6270/125
37	Wakulla	W-12114 P-696	Placid Oil Co. 1 USA Unit 27-2	Sec. 27 T2S, R3W	99	12242	7-1	Diabase	12220/22
38	Walton	W-11374 P-587	Texas Gas Expl. 1 - International Paper Co.	Sec. 5 T5N, R20W	294	12028	7-1	Diabase	11610/30 11997/31
39	Washington	W-12347 P-738	Hunt Petr.-Int. Paper Co.	Sec. 11 T4N, R14W	84	14044	7-1	Diabase	10840/20 13390/10 13470/30 13510/10 13670/50

¹Reference: 1 = Cole, 1944; 2 - Applin, 1951; 3 - Applin and Applin, 1965; 4 - Bass, 1969; 5 - Milton and Grasty, 1969; 6 - Milton, 1972; 7 - Barnett, 1975; 8 - Mueller and Porch, 1983; and 9 - Present Study.

Data: 1 - Megascopic Description; 2 - Petrography; 3 - Major Element Chemistry; 4 - Trace Element Chemistry; and 5 - Radiometric Age(s).

Figures 2 and 3 show the generalized lithology and structure of the Florida basement, respectively (see Part Two for further discussion). A comparison of these figures with Figure 1 reveals that intrusions of basalt and diabase most commonly occur in the Mesozoic basins of Florida and are least common in the igneous terrane of central Florida. The exact intrusive form of each tholeiitic body is unknown. In general, these rocks occur as dikes, sills (or sheets) and flows, but detailed core descriptions, additional petrographic analyses and geophysical data are required in order to be more specific.

The variation in depth to these mafic rocks is predominantly controlled by their geographical position relative to the Peninsular Arch. For example, diabase is encountered at a depth of approximately 3,500 feet in Columbia County, whereas in Wakulla and Hardee Counties, diabase or basalt is present at a depth of approximately 12,000 feet (Figure 3 and Table 4). The position (depth) of these rocks relative to

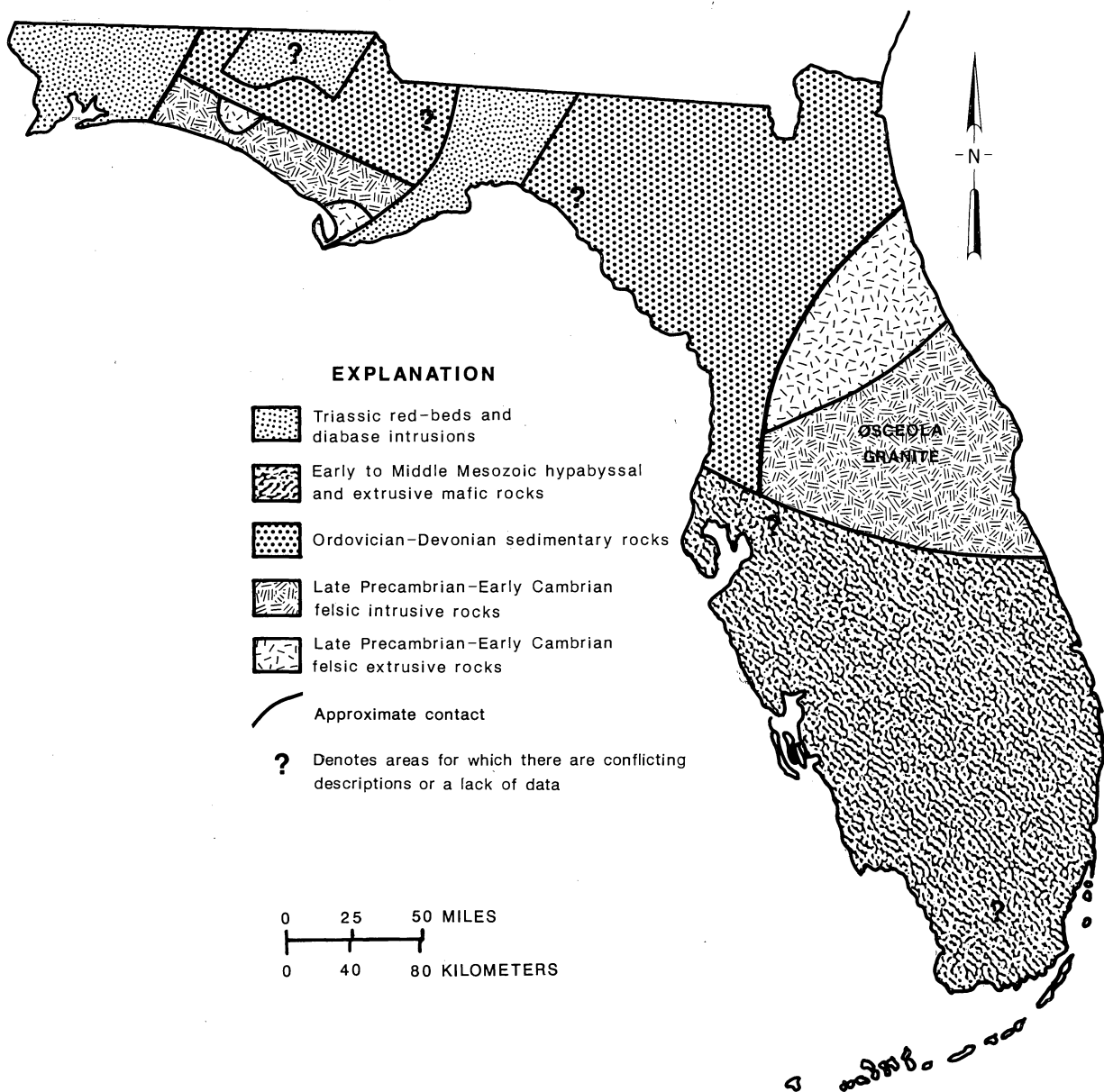


Figure 2. Lithology of the pre-Middle Jurassic Florida basement surface.

the post-rift unconformity as well as petrographic evidence (fine grained and vesicular textures) suggests that emplacement and crystallization of these tholeiitic melts was at or near the surface. An eight to ten-thousand foot variation in present-day depth to these rocks does not reflect the initial variation in their original depth of emplacement. Variations in topography during emplacement caused the initial differences, especially for the extrusive rocks. Post-Middle Jurassic subsidence of the flanks of the Peninsular Arch has further changed the apparent relative depth of emplacement (or extrusion) of these tholeiitic rocks.

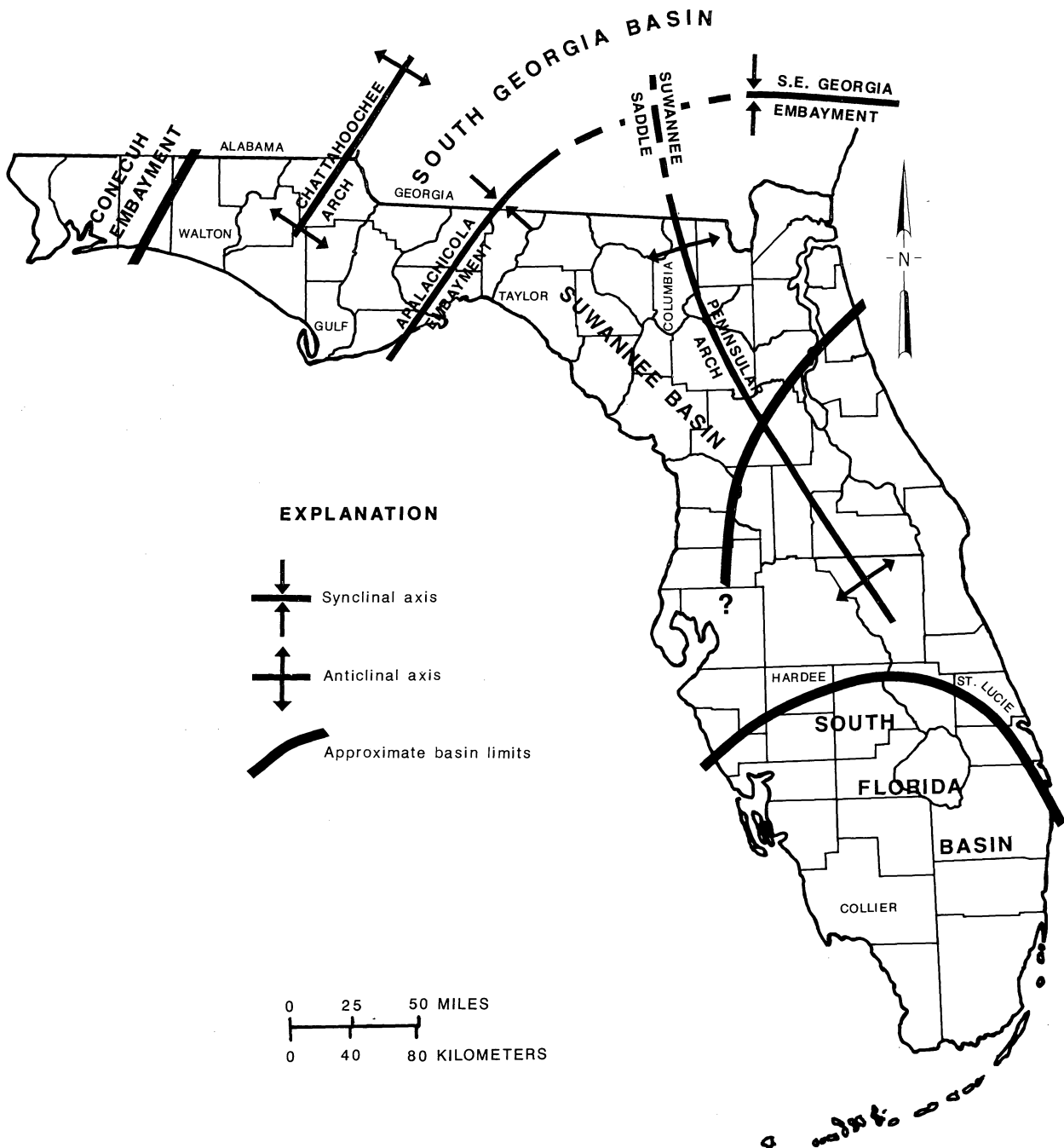


Figure 3. Florida basement pre-Middle Jurassic tectonic features.

PETROGRAPHY

The major mineral constituents of diabase are calcic plagioclase and clinopyroxene, most commonly augite but also pigeonite, with or without olivine and orthopyroxene. Petrographic descriptions of 11 Florida diabase or basalt samples have been previously reported (Bass, 1969; Milton and Grasty, 1969; Barnett, 1975). In general, the rocks they describe contain about 50 percent plagioclase (most commonly labradorite), 40 percent clinopyroxene (augite), 10 percent accessory minerals or alteration products and occasionally trace amounts of olivine. The most common accessory phases are opaques (titanomagnetite?), granophyre (intergrowths of quartz and potassium feldspar), biotite, apatite, sphene, epidote and calcite. Alteration of augite and olivine is indicated by the presence of chlorite, magnetite, montmorillonite, iddingsite and serpentine. Plagioclase occasionally alters to sericite. Diabase textures range from fine to medium grained, equigranular-intergranular to subophitic. Basalts analyzed in this group are very fine grained and holocrystalline. Porphyritic textures contain a phenocryst assemblage of either plagioclase, clinopyroxene plus plagioclase, or olivine.

Petrography of samples listed in Table 5 is tabulated in Appendix 1. These new data are in general agreement with published results; however, olivine is not observed in any of the Florida Geological Survey (FGS) samples. One must conclude that either the occurrence of olivine tholeiite in Florida is rare or that the sampling screen (see next section) for this study created a bias. In general, textures of the FGS samples are equigranular-intergranular and occasionally subophytic. Porphyritic samples contain plagioclase or plagioclase plus clinopyroxene phenocrysts. With respect to Cummins' (1987) classification, the FGS samples belong to the granophyre-bearing (GRB) and spinel-granophyre absent (SGA) petrographic groups.

Table 5. Sample location data.

LAB. NO.	COUNTY	WELL NO.	DEPTH OR DEPTH INTERVAL (FT.) BELOW MSL	MAP NO. (FIGURE 1)
FGS-1	Taylor	W-1877	6180	32
FGS-2	Taylor	W-1877	6207 - 6219	32
FGS-3	Taylor	W-1877	6228 - 6246	32
FGS-4	Highlands	W-3578	12614 - 12629	8
FGS-5	Nassau	W-336	4820 - 4822	24
FGS-6	Hardee	W-1655	11888 - 11932	6
FGS-7	Levy	W-2012	4350 - 4360	18
FGS-8	Levy	W-2012	4356 - 4359	18
FGS-9	Columbia	W-1789	3529.5 - 3555	1
FGS-10	Columbia	W-1789	3555 - 3562	1
FGS-11	Jefferson	W-1854	7789 - 7791	13
FGS-12	Nassau	W-10715	5429	24
FGS-13	Nassau	W-10715	5437	24
FGS-14	Nassau	W-10715	5444	24

SAMPLING AND ANALYTICAL METHODS

Table 5 shows the county, well number and depth interval for 15 diabase and basalt samples from the Florida Geological Survey core repository in Tallahassee, Florida. Map numbers listed on Table 5 correspond to core hole locations shown on Figure 1. Cuttings and core chips from the depth intervals listed for each well in Table 4 were petrographically screened in an attempt to yield only homogeneous, fresh and aphyric samples for geochemical analysis by atomic absorption (AA) and x-ray fluorescence (XRF). All samples were powdered in a Siebtechnik tungsten-ring rock pulverizer and split prior to analysis. A thin section from each core was also prepared. Petrographic identification of alteration products was facilitated by a Philips APD 3520 x-ray diffractometer. Loss on ignition (LOI) was determined gravimetrically by measuring the weight loss of a one-gram powder sample after being heated in a muffle furnace for one hour at 800°C. Solutions for AA analysis were made from rock powders using a hydrofluoric-boric acid microwave dissolution technique modified from Langmyhr and Paus (1968). Concentrations of Na, Fe (total Fe as Fe_2O_3) and Mg were determined on a Perkin-Elmer model 303 atomic absorption spectrometer modified with a digital signal integrator. In preparation for XRF analysis, sample powders were mixed with a boric acid binder (7:1) and pellet-pressed into Spec-caps. The pellets were analyzed by an automated Philips PW 1410 x-ray fluorescence spectrometer (W-tube) for the major elements Si, Ti, Al, Mn, Ca and K, and the trace elements P, Ba, Cr, Cu, Ni, Rb, Sr, V, Y, Zn and Zr.

Calibration curves for each element were set up using the following rock standards: USGS-W-2, USGS-BCR-1, QMC-I-3, USGS-DNC-1, USGS-AGV-1 and GSJ-JB-1. Analytical precision was calculated as coefficient of variation (CV) from duplicate analyses of all samples. Acceptable values of CV for major and trace elements are less than 3 percent and 10 percent, respectively. All major and trace elements fall within this range except for Cu, Rb and Y (< 20 CV). Accuracy was determined by comparison of observed versus expected values for U.S. Geological Survey standards W-2, DNC-1 and BCR-1. These results, as well as precision analyses, are summarized in Appendix 2.

Results

Major and trace element chemistry, mafic index and normative mineralogy (a calculated, theoretical mineral assemblage) of samples collected for this study are listed in Table 6. Although five samples have a high volatile content (greater than 2 weight percent loss on ignition), indicating significant alteration, most of the samples appear to have retained their original geochemistry. Alteration of sample FGS 9 may have lowered the silica concentration enough to change its normative mineralogy from quartz- to olivine-normative. Note that a composite sample (FGS 10) taken from the same core a few feet lower is quartz-normative.

Of the six Florida tholeiite samples previously analyzed (Table 3), only three are included in the present data base. Samples MG 2 and MG 5 are excluded due to evidence of alteration (high concentrations of K_2O and/or volatiles greater than 5 percent). Sample MP 14 is excluded for the following reasons (1) despite its apparent low volatile content, Mueller and Porch (1983) report that the sample is altered; (2) MP 14 is olivine-normative and plots far from any of the observed geochemical trends (the petrogenetic significance of a magma type (OLN) based upon one sample is highly speculative); and (3) Hurlbut et al. (1987) suggest that MP 14 belongs to an Upper Jurassic-Lower Cretaceous alkalic magma intrusion episode. Due to the questionable OLN character of FGS 9, all samples are classified as quartz-normative tholeiites. In the following discussion, the Florida tholeiite data base consists of all FGS samples and samples MP 12, MP 13 and MG 6 (Table 3).

There appears to be no systematic chemical variation in the samples with respect to geography. The distribution of Zr on Figure 1 is shown as an example. Chemical variation between samples in a given core (same intrusion) is observed in some cases. A comparison of Tables 5 and 6 reveals that individual (?) intrusion chemistry ranges from strongly differentiated (e.g., W-1877, mafic index (MI) ranges from 69.8 to 87.7) to very homogeneous (e.g., W-10715, MI ranges from 70.7 to 71.7).

Previous studies indicate that all four magma types of Weigand and Ragland (1970) are present in Florida. However, when considering the accepted data base, only the LTQ and HFQ (and OLN?) types are present. These data plot as a linear trend from the LTQ field through the HFQ field on the MI versus TiO₂ diagram of Figure 4. As expected, the samples with a granophyric texture (Appendix 1) plot on the more differentiated portion of this trend (higher MI values).

All major and trace elements have been plotted as dependent variables against the MI. Concentrations of SiO₂, TiO₂, Fe₂O₃*, Na₂O, K₂O, P₂O₅, Ba, Cu, Rb, V, Y, Zn and Zr increase with increasing MI values (positive slope), whereas concentrations of Al₂O₃, MgO, CaO, Cr and Ni decrease with increasing MI

Table 6. Major and trace element compositions and normative mineralogy of Florida tholeiite. MI calculated as $\text{Fe}_2\text{O}_3^*/\text{Fe}_2\text{O}_3^* + \text{MgO}$, total Fe as Fe_2O_3^* , normative minerals calculated on a dry basis with $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.1$, BD - below detection. See Table 3 for explanation Norm Abbreviations.

WEIGHT PERCENT	FGS1	FGS2	FGS3	FGS4	FGS5	FGS6	FGS7	FGS8	FGS9	FGS10	FGS11	FGS12	FGS13	FGS14
SiO ₂	53.4	52.4	52.1	51.0	51.5	51.7	52.6	52.8	48.4	50.8	51.2	51.9	51.6	52.2
TiO ₂	2.15	0.95	1.20	1.26	0.76	1.95	1.89	1.86	1.23	1.29	0.82	1.32	1.35	1.32
Al ₂ O ₃	13.1	14.7	13.8	13.3	13.9	13.1	13.1	13.1	13.1	13.4	13.6	13.6	13.8	13.9
Fe ₂ O ₃ *	17.8	12.4	13.8	11.0	11.0	14.9	13.1	14.1	14.5	14.2	10.9	13.2	13.3	13.4
MnO	0.22	0.19	0.21	0.04	0.21	0.22	0.15	0.18	0.22	0.22	0.22	0.22	0.22	0.22
MgO	2.48	3.79	5.98	4.86	7.68	4.21	3.02	3.74	6.60	6.73	7.13	5.2	5.53	5.49
CaO	7.43	9.63	10.2	10.5	11.3	8.13	8.25	6.88	9.34	10.7	11.0	9.82	9.92	9.76
Na ₂ O	2.74	2.99	2.44	2.46	2.05	2.38	2.80	2.75	2.80	2.18	2.16	2.55	2.42	2.50
K ₂ O	1.30	0.84	0.61	0.37	0.18	1.39	1.82	1.75	0.31	0.23	0.20	0.51	0.60	0.67
P ₂ O ₅	0.30	0.17	0.15	0.18	0.09	0.44	0.35	0.37	0.13	0.17	0.09	0.25	0.22	0.25
LOI	0.77	0.72	0.53	4.92	1.79	2.60	4.62	2.31	2.91	1.22	2.01	1.56	0.53	0.50
TOTAL	101.7	98.8	101.0	99.9	100.5	101.0	101.7	99.8	99.5	101.1	99.3	100.1	99.5	100.2
MI	87.8	76.5	69.8	69.4	58.9	78.0	81.3	79.0	68.8	67.9	60.5	71.7	70.7	70.9
WEIGHT PERCENT NORMS														
Q	7.11	3.53	2.49	5.92	3.25	5.51	5.78	6.22	0.00	2.00	3.37	4.45	3.63	3.76
OR	7.74	5.12	3.63	2.33	0.06	8.46	11.2	10.7	1.92	1.38	1.23	3.10	3.62	4.02
AB	23.4	26.1	20.8	22.1	17.8	20.7	24.7	24.2	24.8	18.7	19.0	22.2	20.9	21.3
AN	19.6	24.9	25.0	25.7	29.4	21.4	18.5	18.7	23.3	26.4	27.8	24.7	25.4	24.9
DI	13.4	19.4	20.4	23.5	22.3	14.4	18.5	11.9	19.9	21.5	22.9	19.6	19.3	18.7
HY	21.5	16.8	23.1	15.8	24.0	22.5	14.9	21.6	18.4	25.2	22.4	20.9	22.1	22.2
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.68	0.00	0.00	0.00	0.00	0.00
MT	2.60	1.86	2.02	1.70	1.64	2.24	1.98	2.13	2.21	2.09	1.66	1.97	1.97	1.97
IL	4.07	1.84	2.27	2.52	1.46	3.77	3.70	3.63	2.42	2.46	1.60	2.55	2.59	2.52
AP	0.66	0.38	0.33	0.42	0.20	0.99	0.80	0.85	0.30	0.38	0.20	0.56	0.49	0.55
PPM														
Ba	253	160	152	151	115	289	335	392	156	185	126	189	193	201
Cr	BD	BD	BD	141	253	BD	BD	BD	677	BD	228	BD	BD	BD
Cu	289	86	109	45	65	193	154	187	125	147	87	57	53	55
Ni	11	23	37	55	65	26	42	31	75	77	55	32	30	33
Rb	36	26	17	10	11	26	52	53	11	10	12	16	23	20
Sr	114	153	128	241	132	243	224	226	152	127	129	136	230	223
V	300	231	283	272	241	313	319	329	307	317	251	301	294	294
Y	55	29	31	19	26	35	36	36	32	41	24	24	22	33
Zn	185	89	94	195	80	126	143	117	101	103	78	106	102	100
Zr	197	122	105	102	83	174	178	182	89	106	85	117	101	111

values (negative slope). No correlations are observed for MI versus MnO and Sr. Figure 5 is a stacked plot of the elements that best correlate with the MI. Trends with positive slopes indicate that the element was not incorporated into the phases that fractionated from the magma, that is, the element was incompatible. Compatible elements (e.g., CaO and Ni) have negative slopes and were thus removed from the magma during fractionation.

The trends shown on Figures 4 and 5 suggest that the data represent a single suite. Some of the data which constitute trends on Figures 4 and 5, as well as subsequent diagrams, may prove to represent portions of other trends not yet delineated due to limited data.

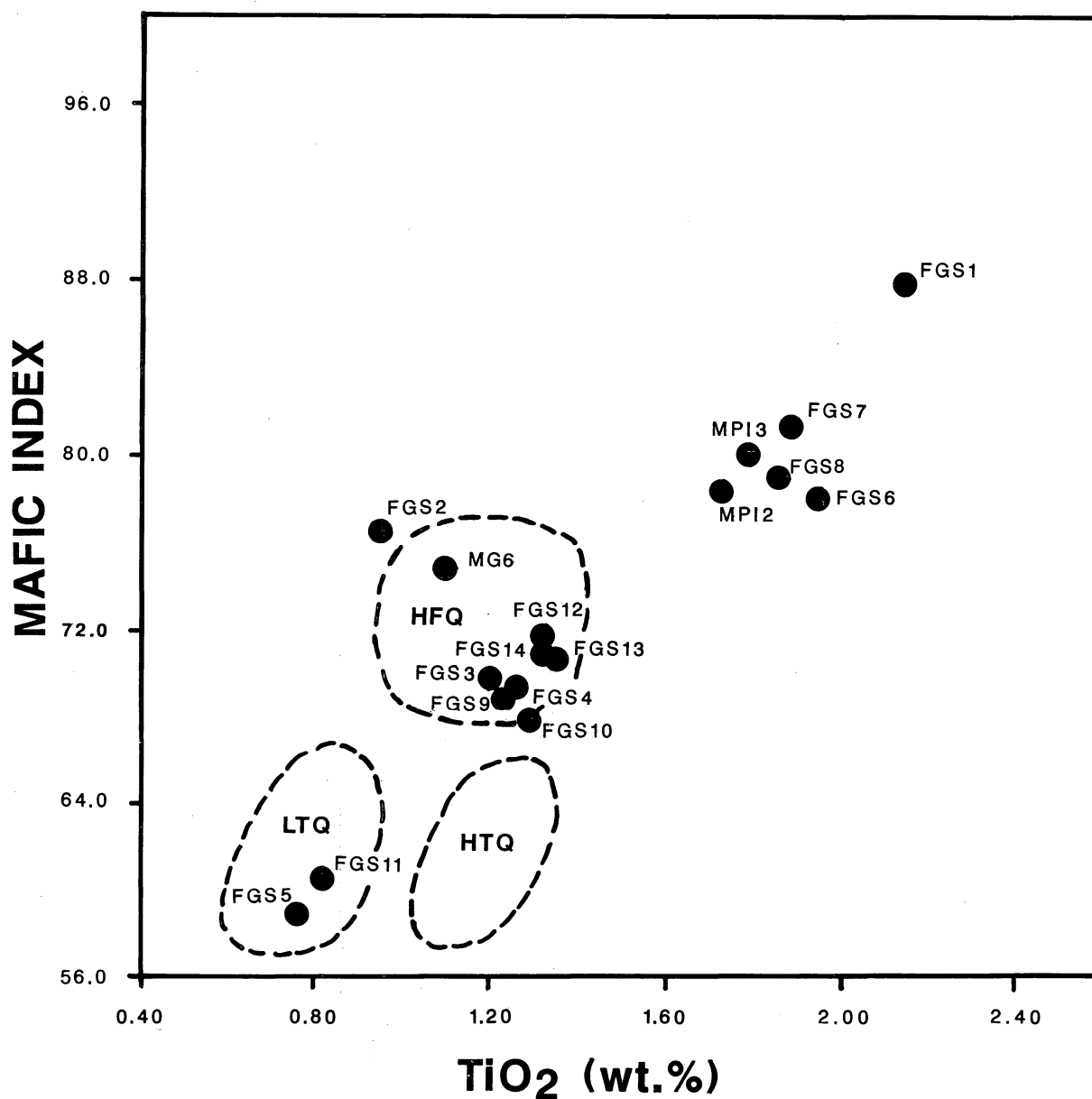


Figure 4. Mafic index ($\text{Fe}_2\text{O}_3^*/\text{Fe}_2\text{O}_3^* + \text{MgO}$) plotted versus TiO_2 (weight percent). Modified from Weigand and Ragland (1970). HTQ is high- TiO_2 , quartz-normative; HFQ is high- Fe_2O_3 , quartz-normative.

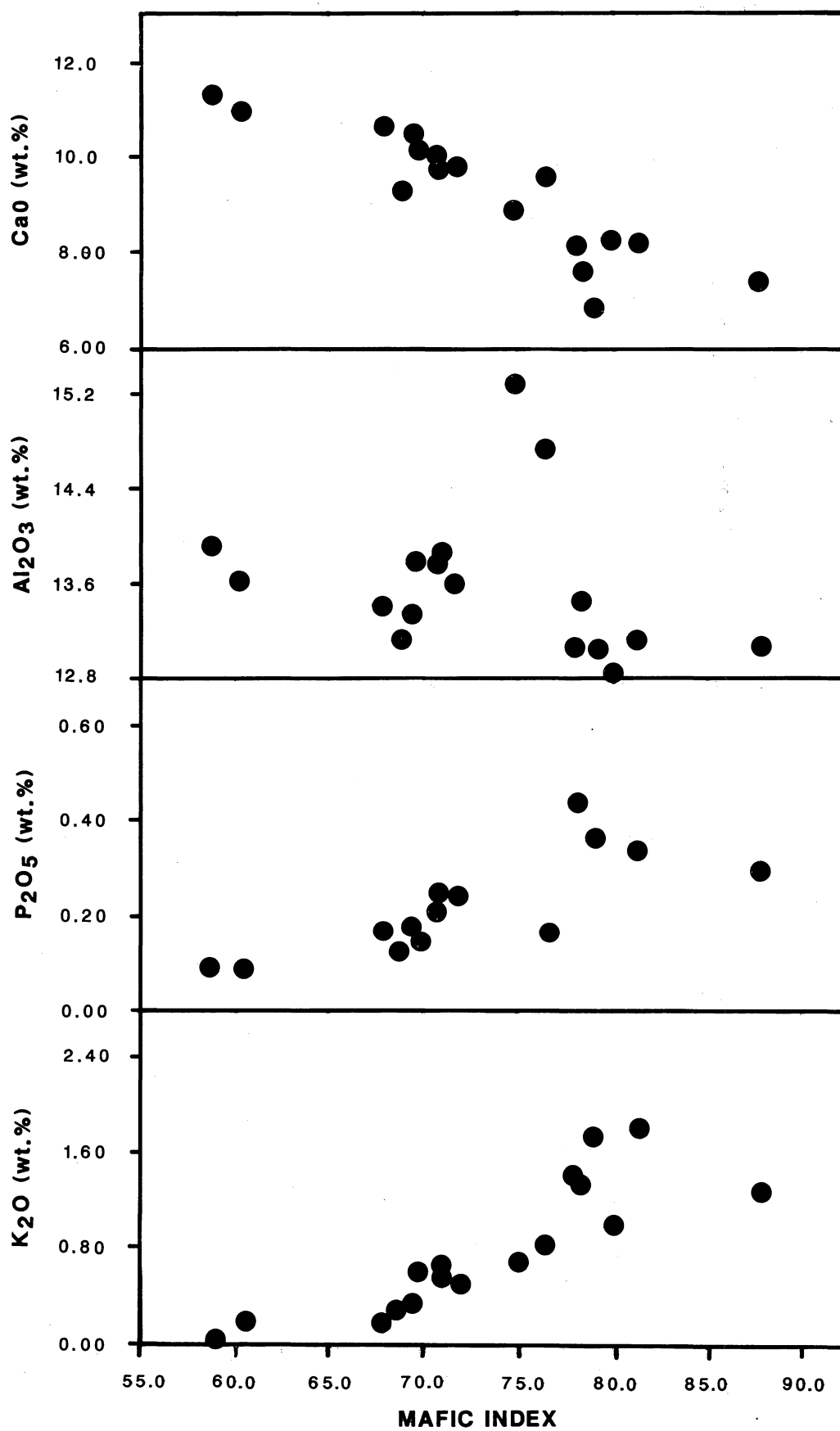


Figure 5. Stacked plots of selected major and trace elements versus the mafic index.

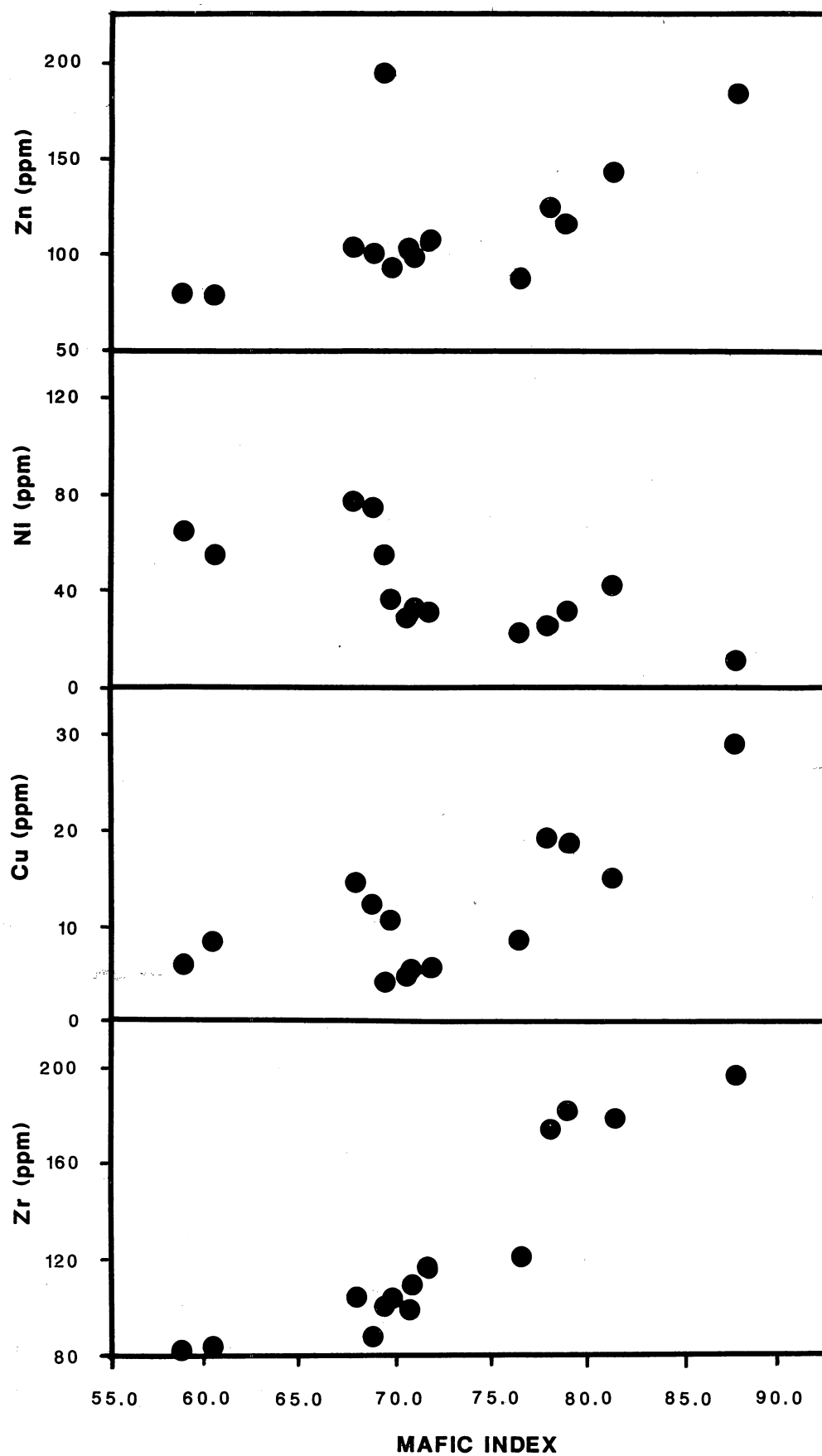


Figure 5. (Continued).

Discussion

PETROGENESIS

The petrogenetic relationship between the high-TiO₂ quartz-normative (HTQ), low-TiO₂ quartz-normative (LTQ) and olivine-normative (OLN) magmas in eastern North America (ENA) has not been totally resolved. One explanation suggests that the HTQ and LTQ magmas are the result of varying degrees of plagioclase, clinopyroxene and olivine fractionation of OLN magmas (Weigand and Ragland, 1970). Smith et al. (1975) contend that olivine fractionation of OLN produced the LTQ; whereas, the same process plus assimilation of orthopyroxene produced the HTQ. In accordance with Green and Ringwood (1967), both of the above studies agree that the OLN magma was produced by partial melting of an upper mantle source. Later studies suggest that the diverse chemistry of these magmas was due to incompatible element wall-rock contamination (Ragland et al., 1971) or magma mixing (Pegram, 1983).

The linear trend on Figure 4 supports the result of previous ENA diabase studies (e.g., Maxey, 1973; and Cummins, 1987) which indicate that the LTQ magma is parental to the high-Fe₂O₃ quartz-normative (HFQ) magma. The Florida tholeiitic suite, however, is much more evolved than any ENA diabases previously reported. The data plot well beyond the HFQ field toward a maximum MI value of 87. A petrogenetic model for the Florida tholeiite must account for this as well as the compatibility of Al₂O₃, MgO, CaO, Cr, and Ni within the fractionating assemblage.

The phenocryst assemblage within the Florida samples can account for most of the observed major and trace element variation. Based upon experimentally determined partition coefficients (Henderson, 1982), fractionation of clinopyroxene from a basaltic magma would noticeably deplete the magma of Mg, Ca, Cr and Ni. Plagioclase fractionation would remove Al₂O₃, CaO and Sr from the system. TiO₂, K₂O, P₂O₅ and Ba are strongly incompatible with respect to plagioclase and clinopyroxene. Therefore, concentrations of these elements would increase as differentiation proceeded. The linear and slightly curvilinear trends on Figure 5 indicate that either the fractionating assemblage remained fairly constant in its chemical composition or that magma mixing or assimilation has occurred. The following discussion supports the former suggestion. Criteria for either magma mixing or assimilation having occurred, such as evidence of end-member magmas, xenoliths, high alkali contents or chemical trends that do not fit a reasonable fractionation model, are not present in the Florida data.

In an attempt to quantify the fractionation assemblage as well as the percent crystallization required to produce the differentiation pattern of the Florida tholeiite, the following linear algebraic expression of Weigand and Ragland (1970) was applied:

$$Y = (Z - NX/100) 100/100-N$$

where: X = composition of accumulated crystals
Y = composition of residual liquid or daughter
Z = composition of the parental magma
N = percent accumulation

Values of X can be calculated by iterating values of N, with Y and Z known. Parent and daughter (residual) magma compositions (Table 7) were determined by computing linear and quadratic regressions of all the elements versus the MI. MI values for FGS 1 and FGS 5 were used as "anchors" to determine these compositions by extrapolation from the curve parallel to the MI axis (x-axis). Correlation coefficients were used to determine whether the data are best represented by a linear or second-order polynomial curve fit.

Table 7 summarizes the results of the fractionation model for a range of 60 to 80 percent accumulation using the calculated parent and daughter magmas. An ideal solution is achieved when the incompatible

Table 7. Petrogenetic model for Florida tholeiite showing calculated compositions and normative mineralogy. See Table 3 for explanation of Norm abbreviations.

WEIGHT PERCENT	DAUGHTER	PARENT	PERCENT ACCUMULATION (N)				
			60	65	70	75	80
SiO ₂	53.4	50.5	48.5	48.9	49.2	49.5	49.7
TiO ₂	2.12	0.73	-0.21	-0.03	0.12	0.26	0.37
Al ₂ O ₃	12.9	13.6	14.1	14.0	13.9	13.9	13.8
Fe ₂ O ₃ *	16.2	11.1	7.7	8.4	8.9	9.4	9.8
MnO	0.19	0.20	0.20	0.20	0.19	0.19	0.19
MgO	2.12	7.73	11.5	10.7	10.1	9.6	9.1
CaO	6.91	11.5	14.6	14.0	13.5	13.1	12.7
Na ₂ O	2.72	2.08	1.64	1.73	1.80	1.86	1.91
K ₂ O	1.71	0.10	-0.98	-0.78	-0.60	-0.45	-0.31
P ₂ O ₅	0.36	0.06	-0.15	-0.11	-0.08	-0.05	-0.02
PPM							
Ba	321	95	-56	-27	-2	20	38
Cu	290	85	-52	-25	-3	16	34
Ni	12	66	102	95	89	84	79
Rb	50	7	-22	-16	-11	-7	-4
Sr	148	111	86	91	95	99	102
V	300	248	213	220	226	230	235
Y	52	28	12	15	18	20	22
Zn	171	88	33	43	52	60	67
Zr	199	63	-28	-10	5	18	29
MI	88	59	40	44	47	49	52
WEIGHT PERCENT NORMS							
AB			14.2	15.1	15.7	16.2	16.7
AN			31.8	31.2	30.7	30.4	29.9
DI			33.9	32.2	30.8	29.4	28.3
HY			3.62	8.6	12.8	16.3	19.9
OL			15.4	11.7	8.43	5.8	2.95
MT			1.15	1.25	1.33	1.41	1.47
IL			0	0	0.23	0.50	0.72

elements reach positive values with increasing values for N. With the exception of K₂O, P₂O₅ and Rb, acceptable values of N range from 70 to 75 percent (Table 7). The negative values for K₂O, P₂O₅ and Rb are problematic. K₂O and Rb may have been selectively added to the magma from the country rock ("wall rock reaction" of Green and Ringwood, 1967). Enrichment of K₂O during alteration of diabase in the Culpeper Basin of Virginia has been observed by Ragland and Arthur (1987). Another related possibility is that alteration of the diabase resulted in scatter among the data (P₂O₅ and Rb) which yielded a regression not representative of fractionation, thus the compositions for those elements used in the model may be incorrect.

Using TiO₂, Ba, Cu and Zr for final criteria, the model gives a value of 70 to 75 percent accumulation of fractionated crystals in order to account for the observed variations in Florida tholeiite chemistry. TiO₂ and Zr become positive between N = 65 and 70 percent, whereas Ba and Cu values become positive between N = 70 to 75 percent. Normative mineralogy of the assemblage at this range in percent accumulation includes approximately 7 percent olivine, 46.5 percent plagioclase (AN = 66), 44.7 percent pyroxene and 1.5 to 2 percent Fe-Ti oxides. If samples FGS 1 and 5 had been chosen to represent daughter and parent magmas, respectively, rather than relying on regression compositions, at N = 75 percent, P₂O₅ and Rb also become positive. In either case, the modeled accumulation assemblage accounts for all compatible element variations.

Weigand and Ragland (1970) and Cummins (1987) report lower values for percent accumulation (N = 65) with respect to differentiation of the ENA diabase suite. This provides further evidence that the Florida tholeiite is more evolved than that of the average ENA suite. However, the Florida tholeiite model assumes that the calculated composition at MI = 59 represents the parental magma for the suite. If the true parental magma is more primitive, that is, higher concentrations of Ni, Ca and a lower MI, the values for N would be lower.

Diabase-petrogenetic studies occasionally apply the Ti-Zr-Y discrimination diagram of Pearce and Cann (1973) to determine paleotectonic environments. On this diagram (Figure 6), the Florida data plot within the calc-alkaline, low-potassium tholeiite and ocean floor basalt fields. This suggests both a converging plate margin and a mid-ocean ridge affinity. Philpotts (1985) has shown a considerably larger set of ENA diabase data to fall within these fields. As indicated by Philpotts (1985), use of "Pearce and Cann (1973) diagrams" as well as other tectonic discrimination diagrams for ENA diabase and basalt may be inappropriate. Similar conclusions have been drawn by Gottfried et al. (1973), Cummins (1987) and Sol (1987) for ENA diabase. Alternatively, the data may suggest that these magmas were generated from multiple source regions (Philpotts, 1985), one of which may be subduction related (Pegram, 1983).

ASSOCIATION

Similar differentiation patterns and fractionation assemblages, as well as proximity and age, suggest that the Florida tholeiite is part of the ENA tholeiitic suite. In this section, possible genetic associations between magmas that are considered proximal to Florida prior to Mesozoic rifting and sea-floor spreading are discussed. Also, a more detailed comparison of the ENA tholeiitic suite to the Florida tholeiite is presented.

Figure 7, modified from Van der Voo et al. (1976), shows the positions of northwest Africa and northeast South America relative to southeastern North America during the early Mesozoic. This figure is presented only to show the geographic relationship of these plates during the emplacement of Mesozoic tholeiitic magmas. Geochemical studies of Early Mesozoic tholeiites from these continents include the following:

Morocco	Bertrand et al., 1982
Surinam	Choudhuri, 1978
Liberia	Testa, 1978

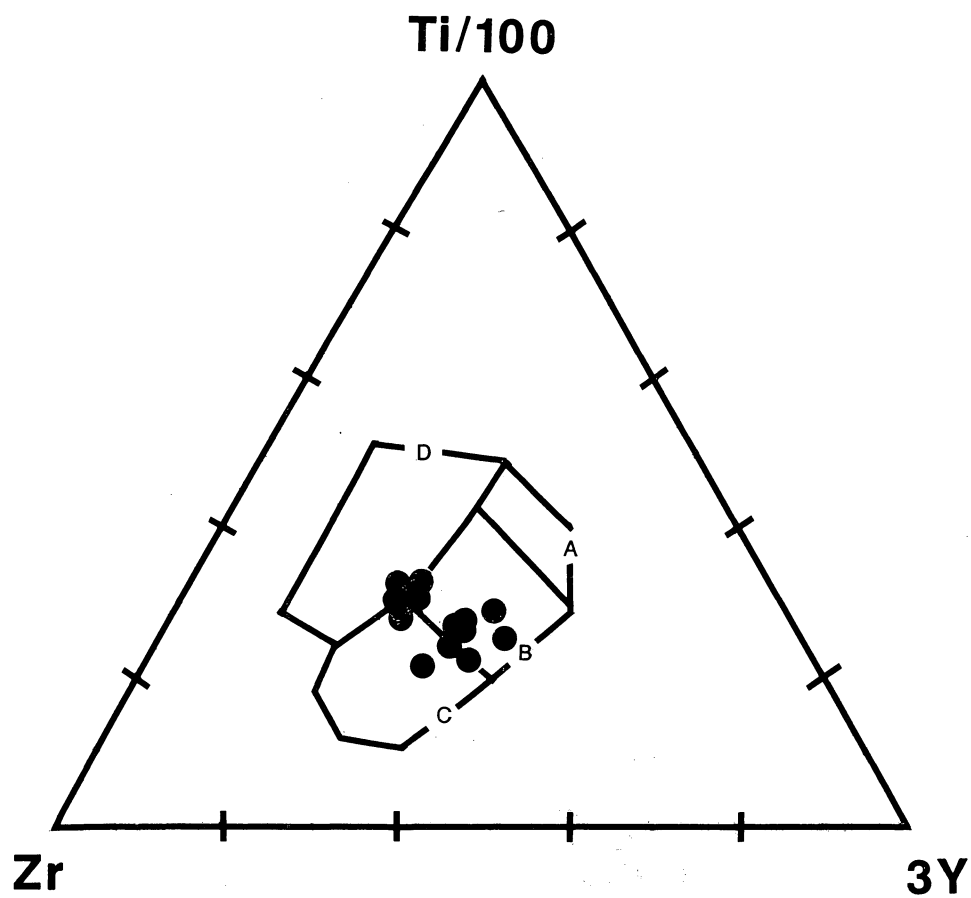


Figure 6. Florida Geological Survey samples plotted on a Ti/100 - 3Y - Zr discrimination diagram (Pearce and Cann, 1973). A - low-K₂O tholeiites; B - ocean floor basalts, low K₂O tholeiites and calc-alkaline basalts; C - calc-alkaline basalts; and D - intra-plate basalts.

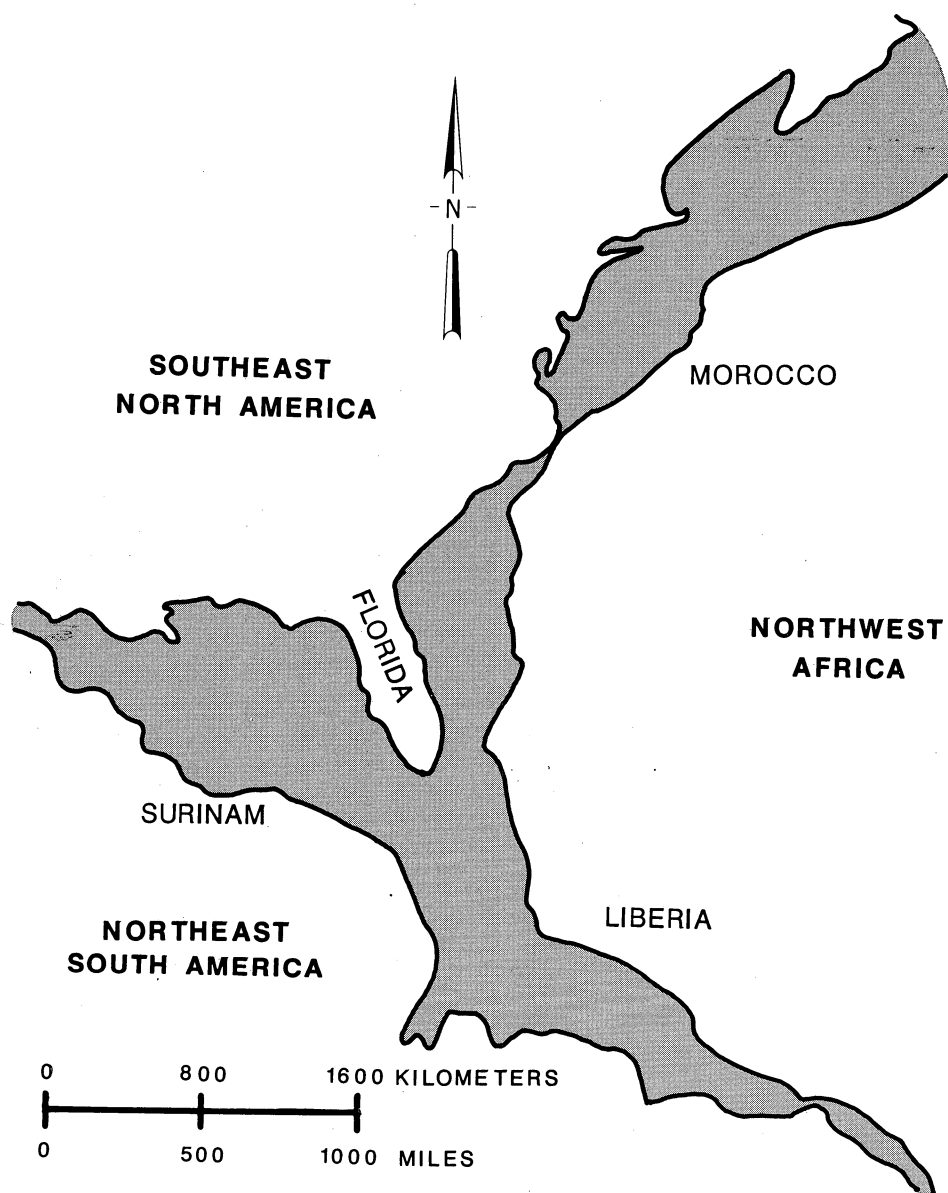


Figure 7. Early Mesozoic pre-rift configuration of the continents. Modified from Van der Voo et al., (1976).

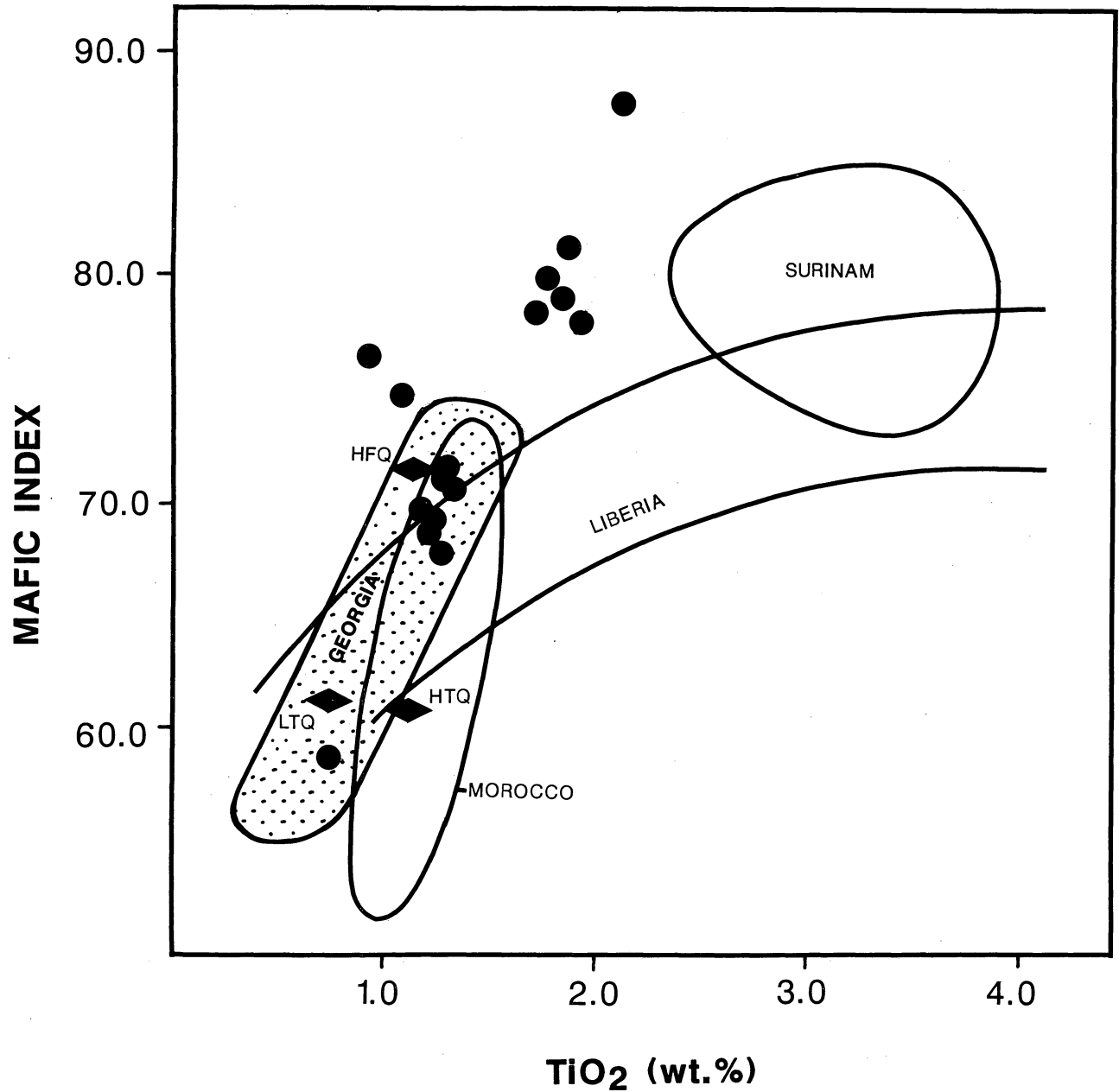


Figure 8. Mafic index plotted versus TiO₂ (weight percent) showing fields of Georgia, Surinam, Morocco and Liberia tholeiites. Florida data plotted as closed circles. Data referenced in text. Solid diamonds denote average magma compositions from Weigand and Ragland (1970).

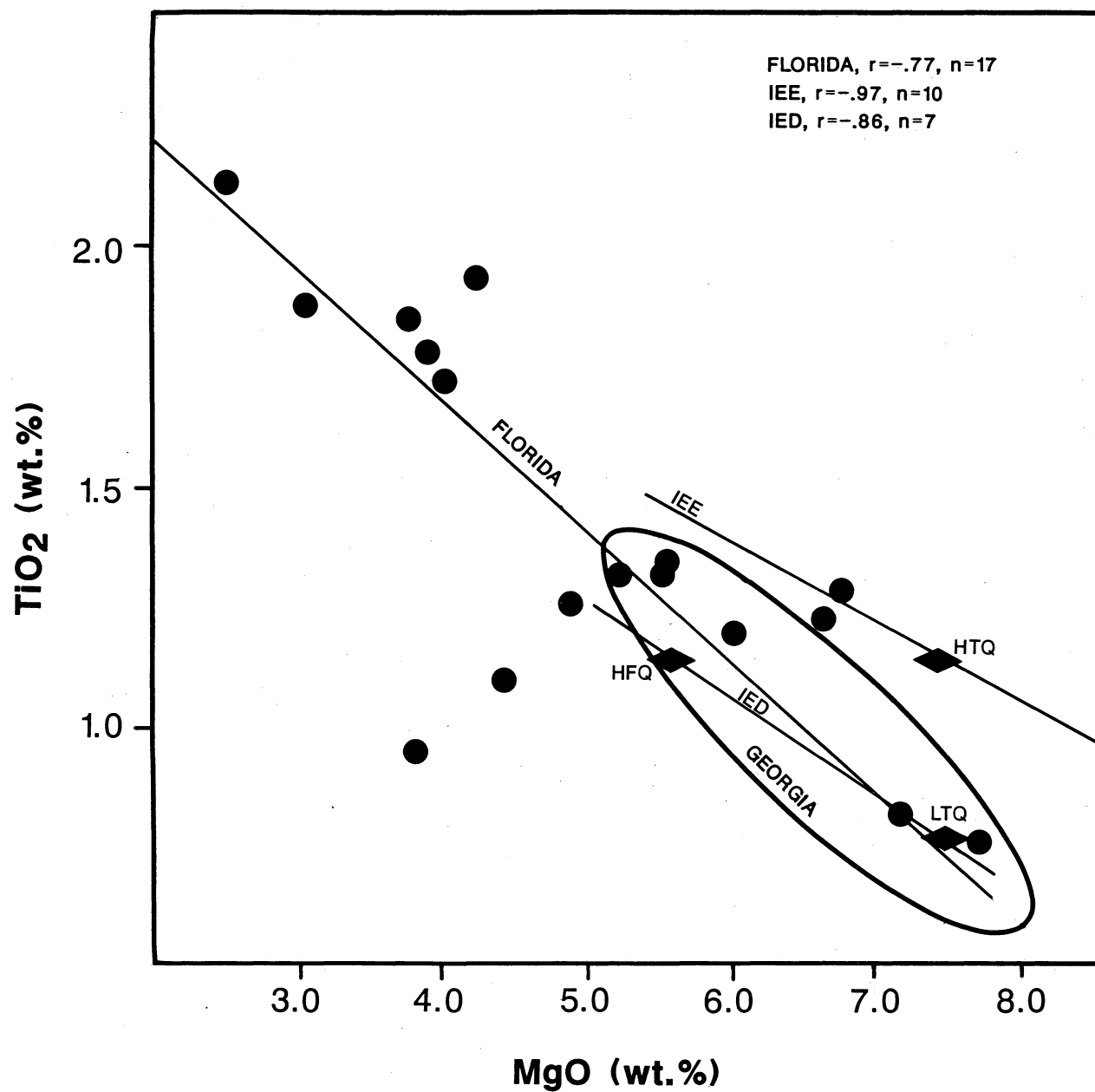


Figure 9a. Comparison plot of TiO₂ versus MgO (both in weight percent) for Florida tholeiite. Georgia field represents dike and sheet data referenced in text. IEE and IED trends from Puffer and Philpotts (1988). Solid diamonds denote average magma compositions from Weigand and Ragland (1970).

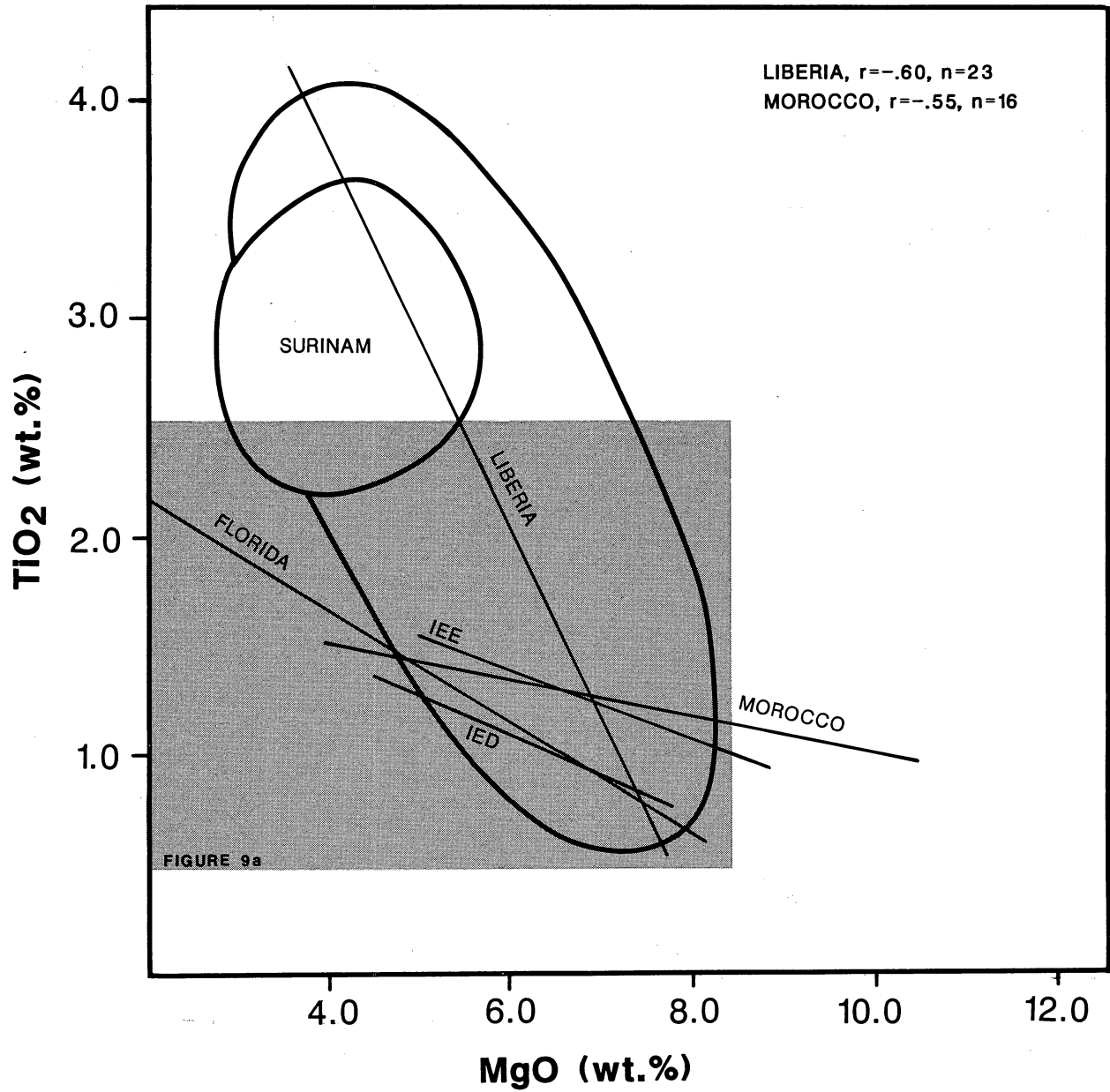


Figure 9b. Comparison plot of TiO₂ versus MgO (both in weight percent) for Florida, Surinam, Liberia and Morocco tholeiites. Fields or linear regressions are shown rather than raw data for simplicity. IED and IEE trends from Puffer and Philpotts (1987). Other data referenced in text.

If any of the magmas from these areas are genetically associated with the Florida magma, one of two trends would be observed on a plot of MI versus TiO_2 . Either the observed trend could be explained by the same parental melt but a different differentiation path (slope) from that of Florida or the trend would be identical to the Florida trend. The data plotted on Figure 8 suggest that there may be a parental relationship between the Florida and Liberia suites. There appears to be no relationship between these suites and the Surinam or Morocco diabase. Figure 8 also shows that the Florida tholeiite and the Georgia diabase dikes (Weigand, 1970; Gottfried et al., 1986) and sheets (Chowns and Williams, 1983) are part of the same differentiation trend.

Rather than utilizing MI versus TiO_2 variations as a means of comparing magma chemistry, some studies have applied the oxide-oxide plot of MgO versus TiO_2 . The incompatible element enriched (IEE) and incompatible element depleted (IED) trends reported by Puffer and Philpotts (1988) were delineated on such a diagram. Their two trends consist of several average compositions of northeast United States basalts and diabase, such as the York Haven Basalt (IEE) and the Sanders Basalt (IED). The MgO - TiO_2 variations for Georgia, Surinam, Morocco and Liberia data are shown as either linear regressions or fields representing data for which a regression is misleading or inappropriate (Figures 9a and 9b). Also, in order to avoid a "noisy" and possibly misleading representation of data, the trends are shown on two scales: Figure 9a shows the Florida data compared to suites with relatively low concentrations and ranges of MgO and TiO_2 ; Figure 9b has expanded axes which allow the Liberia and Surinam fields and the Morocco trend to be shown in their entirety. Puffer and Philpotts' (1988) IEE and IED trends are shown for comparison. Evaluation of the trends suggests (1) Florida, Georgia and IED diabase and basalts may be co-genetic; (2) a genetic relationship may exist between the IEE and Morocco rocks; (3) Liberian diabase has undergone differentiation (i.e., decreasing MgO content) from a parental composition that is approximately chemically equivalent to that of the Florida, Georgia and IED magmas; and (4) the Surinam data show no trend and are probably unrelated.

Numerous studies, such as Gottfried et al. (1983) and Pearce and Cann (1973), have demonstrated that bivariate plots of incompatible elements can discriminate between magma types because parental and source magma compositions are sensitive to incompatible element ratios. Constant ratios on such a diagram would plot as an array of trends that intersect the origin, thus indicating that the elements are equally incompatible with respect to the evolving magmas. Figure 10 is a plot of $\text{Ti}/100$ versus Zr for the Florida, Georgia, Morocco and Surinam tholeiite and average compositions of Weigand and Ragland's (1970) three quartz-normative magma types. A comparison of lines regressed through these data reaffirms a prior conclusion drawn from Figures 8 and 9, namely that the Florida tholeiite is not genetically related to the Morocco and Surinam magma systems. Unfortunately, no trace element data are available for the Liberian suite. Assuming that the Florida samples represent a single magmatic suite, Figure 10 suggests that the Georgia tholeiitic dikes had a slightly different source composition than the Florida diabase. Note, however, that three Florida samples (FGS 2, 5 and 11) plot on the Georgia trend. This scatter may be due to clinopyroxene and/or ilmenite-magnetite fractionation, or the presence of clinopyroxene phenocrysts.

For comparison, the IEE and IED trends (Puffer and Philpotts, 1988) are also plotted on Figure 10. Again, the Florida trend is almost identical to the IED trend, which suggests that the two suites share the same (or chemically identical) source and style of differentiation. The negative slope of the IEE trend suggests that the suite has undergone strong fractionation of a Ti-enriched phase, probably ilmenite. TiO_2 enrichment in a parent magma may be due to partial melting of the source at different depths. Increasing depths of basaltic magma generation leads to an increase in TiO_2 content (MacGregor, 1969).

Isotopic studies and further geochemical investigation of early Mesozoic tholeiites in northwest Africa (e.g., Mauritania, Senegal) and northeast South America (e.g., French Guiana, Venezuela) are needed in order to define better the relationships between these magmas and the Florida tholeiitic suite. Additional chemical analyses of the subsurface tholeiites in the southeastern United States are needed in order to determine whether the relationships observed between the olivine- and quartz-normative magmas farther north can be applied to the tholeiite in the Florida-Georgia region. The relationship between the Mesozoic mafic and felsic rocks in the Florida basement requires further study to enable the development of a more comprehensive petrogenetic model of the Mesozoic igneous rocks of Florida.

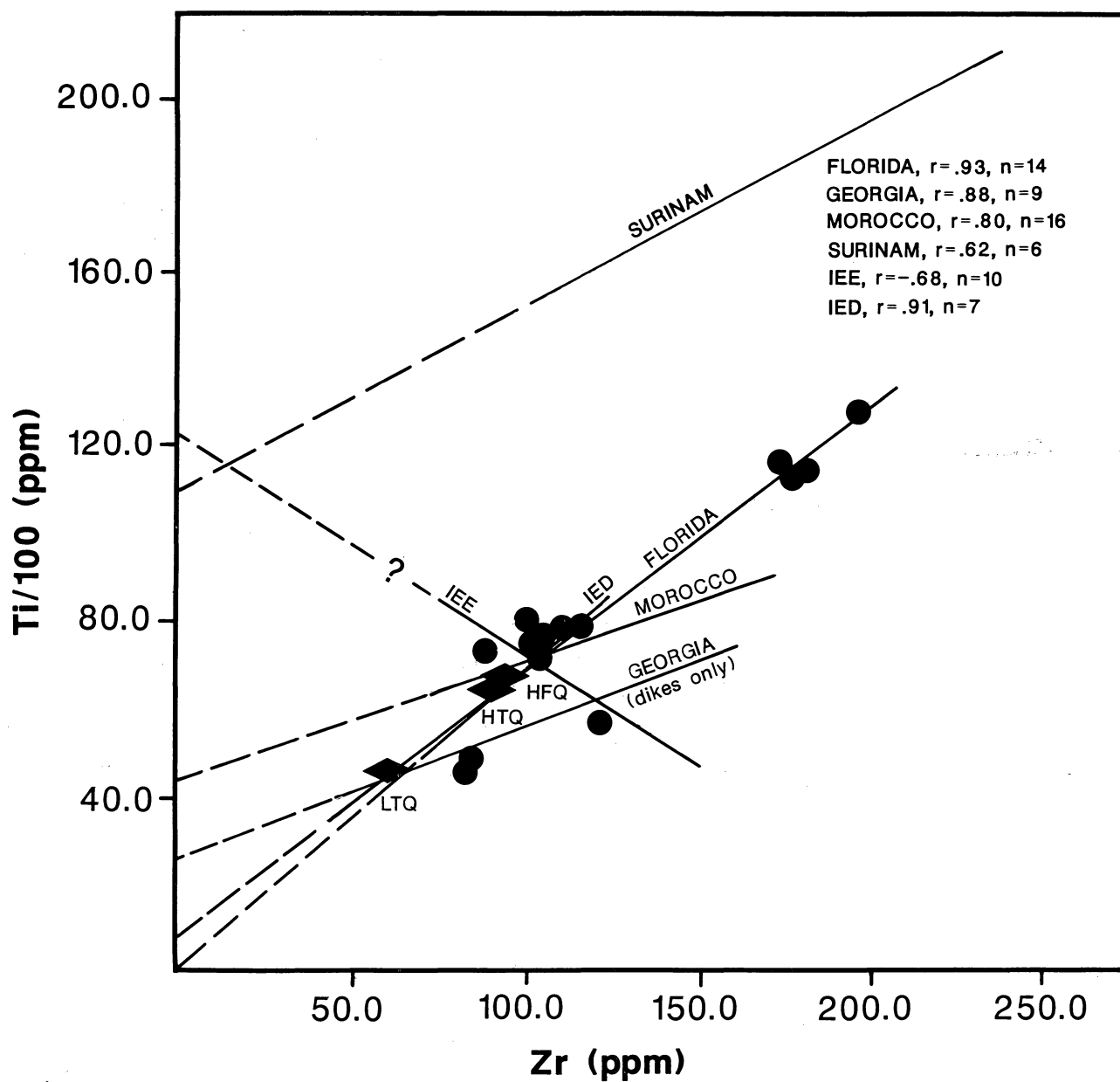


Figure 10. Ti/100 (ppm) plotted versus Zr (ppm) showing Florida tholeiitic trend. Linear regressions through data from Surinam, Morocco, Georgia (dikes only) and northeastern United States (IED and IEE, see text) are also shown. Data referenced in text. Solid diamonds denote average magma compositions from Weigand and Ragland (1970).

Conclusions

- 1) Early Mesozoic tholeiite from the subsurface of Florida plots as a trend from the low-TiO₂ quartz-normative (LTQ) through the high-Fe₂O₃ quartz-normative (HFQ) magma types of Weigand and Ragland (1970) and is more differentiated than the average eastern North America diabase suite.
- 2) Seventy to 75 percent accumulation of a fractionation assemblage containing plagioclase (46 percent), pyroxene (45 percent), olivine (7 percent) and Fe-Ti oxides (1.5 to 2 percent) accounts for the differentiation patterns observed in the Florida quartz-normative magma. Petrographic analysis confirms this model in that phenocrysts of plagioclase, clinopyroxene and iddingsite (after olivine?) are observed either in this study or in previous investigations.
- 3) Major element data suggest that the Florida, Georgia, Liberia and northeastern United States incompatible element depleted (IED - Puffer and Philpotts, 1988) tholeiite may have had the same parental magma or different parental magmas of the same composition. Ti-Zr ratios possibly indicate that the Surinam, Morocco, Georgia and northeastern United States incompatible element enriched (IEE - Puffer and Philpotts, 1988) quartz-normative tholeiites had different source compositions than the Florida and IED tholeiites. Also, the IED and Florida tholeiite may have been derived from the same parental and source compositions.
- 4) MgO-TiO₂ systematics indicate that the Florida, Georgia and IED tholeiites are co-genetic. The same relationship may exist between the IEE and Morocco tholeiites.
- 5) Available data suggest that there is no apparent systematic geochemical variation in the Florida tholeiite with respect to geography.

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Appendix 1. Petrography of Florida tholeiite analyzed in this report.

SAMPLE	GRAIN SIZE	DEGREE OF ALTERATION	TEXTURE	PHENOCRYSTS	GROUNDMASS	ALTERATION/ ACCESSORY MINERALS	COMMENTS
FGS 1*	Medium	Moderate-High	Intergranular, Porphyritic	PL (<1%)	PL>CPX>OP>GR	AP, BI, CH, HB, SER	
FGS 2	Coarse	Moderate	Subophytic, Porphyritic	PL + CPX(<5%)	PL>CPX>OP>GR	AP, BI, CH, HB, SER	
FGS 3*	Medium-Coarse	Fresh	Subophytic, Porphyritic	CPX + PL (<5%)	PL>CPX>OP>GR	AP, CH, HB	
FGS 4	Fine	Moderate-High	Trachytic, Ophimottled Vesicular, Porphyritic	PL (<1%)	PL>CPX>OP	CH, CT, ZT, SER	Vesicles filled with microcrystalline zeolite
FGS 5	Medium	Fresh	Isogranular, Trachytic, Equigranular		PL = CPX>OP	BI	
FGS 6	Fine	Moderate	Isogranular, Trachytic, Porphyritic	PL + CPX (<1%)	PL>CPX>OP	AP, CH, HB, ZT	
FGS 7	Medium-Coarse	Moderate-High	Intergranular, Equigranular		PL>CPX>OP	AP, BI, CH, SER, ZT	
FGS 8	Medium	Moderate	Intergranular, Equigranular		PL>CPX>OP>GR	AP, BI, CH, SER	
FGS 9	Medium	Moderate	Intergranular to Isogranular, Equigranular		PL>CPX>OP	BI, CH	Skeletal opaques
FGS 10	Medium	Fresh	Intergranular, Spherulitic, Equigranular		PL>CPX>OP	BI, CH	Zeolite filled vein
FGS 11	Medium	Fresh	Isogranular to Intergranular, Equigranular		PL>CPX>OP	CH	
FGS 12-14*	Fine-Medium	Moderate	Isogranular to Intergranular, Porphyritic	PL	PL = CPX>OP	AP, CH, SER	

Grain sizes are Fine (≤ 0.1 mm), Medium (> 0.1 mm, < 1.0 mm) and Coarse (≥ 1.0 mm). Abbreviations for major mineral constituents are PL - Plagioclase, CPX - Clinopyroxene (Augite), OP - Opaques, (Fe - Ti Oxides), GR - Granophyre (intergrowths of Quartz and K-Feldspar). Abbreviations for alteration and accessory minerals include: AP - Apatite, BI - Biotite, CH - Chlorite, CT - Calcite, HB - Hornblende (uralite? in the alteration of clinopyroxene), SER - Sericite, ZT - Zeolites; * - indicates that thin-section does not exactly represent sampled interval on Table 5.

Appendix 2. Analytical accuracy (observed versus expected values) and precision (coefficient of variation) for geochemical data. ND - not determined.

Weight Percent	USGS-W-2		USGS-BCR-1		Coefficient of Variation
	Observed	Expected	Observed	Expected	
SiO ₂	52.1	52.1	54.6	54.89	0.49
TiO ₂	1.05	1.06	2.17	2.22	1.49
Al ₂ O ₃	15.6	15.5	14.0	13.7	0.22
Fe ₂ O ₃ *	11.1	10.8	13.3	13.5	0.53
MnO	0.17	0.17	0.19	0.19	0.79
MgO	6.48	6.37	3.50	3.49	0.72
CaO	10.8	10.8	7.75	6.98	0.67
Na ₂ O	ND	2.20	3.24	3.29	0.34
K ₂ O	0.68	0.63	1.95	1.68	1.14
P ₂ O ₅	0.17	0.14	0.39	0.33	8.69
<u>PPM</u>					
Ba	175	174	748	675	1.06
Cr	73	92	[253	270]**	3.20
Cu	105	106	29	18	19.3
Ni	70	70	12	16	3.67
Rb	15	21	40	47	16.1
Sr	193	192	325	330	2.78
V	248	259	330	399	1.12
Y	29	23	39	37	18.5
Zn	78	80	115	120	1.99
Zr	114	100	212	190	5.32

**Values for Cr in USGS-BCR-1 are below detection - Bracketed values are from analyses of USGS-DNC-1.

PART II - AN OVERVIEW OF FLORIDA BASEMENT GEOLOGY

Discussion

Basement rocks in Florida have been variably defined to include rocks which are pre-Mesozoic (Applin, 1951), pre-Cretaceous (Milton and Grasty, 1969; Bass, 1969), early Paleozoic (Milton, 1972) and sub-Zuni (Barnett, 1975). The variation in definition of the Florida basement is due to the numerous uses of the term "basement." Basement may be defined as structural, stratigraphic, seismic or petrologic. Recent literature has generally accepted the pre-Cretaceous surface as an appropriate upper limit of the Florida basement (Klitgord et al., 1984; and Dallmeyer et al., 1987). In this context, "basement" refers to stratigraphic basement below a regionally recognizable and tectonically significant unconformity. This context is considered to be the most appropriate. The unconformity separates pre- to syn-rift rocks from overlying sedimentary rocks deposited during post-rift passive margin sedimentation.

In Florida, the oldest rocks overlying this unconformity are Middle Jurassic in age (Sigsby, 1976; Braunstein et al., 1988). Thus, "pre-Cretaceous" does not accurately constrain the basement (post-rift unconformity) surface. In addition, existing pre-Cretaceous maps (e.g., Dallmeyer et al., 1987) are technically mislabeled because the maps do not include Jurassic sedimentary units. Specifically, the Jurassic Werner Anhydrite, Louann Salt, Norphlet Sandstone, Smackover Formation, Haynesville Formation and the Cotton Valley Group of the central and western Florida panhandle and the Wood River Formation of south Florida are not included in any "pre-Cretaceous" basement map mentioned above. Chowns and Williams (1983) use both the terms "pre-Cretaceous" and "pre-Upper Jurassic" in reference to basement rocks in their paper. In order to alleviate these problems, the present study refers to the Florida basement surface as pre-Middle Jurassic. This age designation more accurately constrains the Mesozoic post-rift unconformity in the subsurface of Florida.

The distribution of pre-Middle Jurassic basement lithologies and tectonic features in the Florida basement are shown in Figures 11 and 12. Based upon data from previous studies (Applin, 1951; Milton and Grasty, 1969; Bass, 1969), as well as more recently reported radiometric age and petrographic data, Barnett (1975) recognized six basement provinces in the subsurface of Florida: 1) a province consisting of Paleozoic and older igneous rocks in the panhandle; 2) a tilted crustal block of Paleozoic sediments in the central panhandle; 3) a northeast trending graben filled with Triassic red beds in the eastern panhandle; 4) an early to middle Paleozoic sedimentary province overlying the Peninsular Arch; 5) an east-central triangular shaped region of upper Precambrian-Lower Cambrian metamorphic and felsic igneous rocks; and 6) a southern Triassic-Jurassic volcanic province.

Since Barnett's (1975) study, improved well coverage resulting in more control points, as well as new radiometric data have led to more recent Florida Basement maps (Dallmeyer et al., 1987; Dallmeyer, 1987). The generalized lithologic map (Figure 11, this report) is the result of an extensive literature review. It is beyond the scope of this study, however, to re-evaluate cuttings for which more than one interpretation exists in the literature. Areas designated by question marks on Figure 11 are those for which there are conflicting descriptions or lack of sufficient data. Other differences between this and previous basement maps are due to: 1) varying definitions of "basement," 2) misidentification of samples (e.g., labeling a weathered (oxidized) basalt as a rhyolite (G. Winston, 1987, personal communication), 3) previous studies describing well bottom samples as basement surface, when in fact the samples are overlain by other basement rocks (e.g., basalt overlying metamorphic rock in St. Lucie County). All unpublished radiometric data discussed in this section are available at the Florida Geological Survey.

The existence of the different names for individual structural features (or similar names for different features) in north Florida is a common problem in the literature. For example, the rift-related Chattahoochee Arch is commonly confused with the overlying Early Tertiary Chattahoochee Anticline; the latter has also been called the Decatur Arch (Puri and Vernon, 1964). Another pertinent example is the Apalachicola Embayment. Fourteen names have been assigned to this feature, including the South Georgia Rift (Daniels et al., 1983), the Tallahassee Graben (Smith, 1983) and 11 other summarized in Table 7 of Schmidt (1984).

Nomenclature of lithotectonic features discussed in this report was chosen based on the following criteria (when applicable): 1) the names accurately describe the location of the feature, named after towns centered on or near the feature's axis; 2) the axis, center or extent of the more regional features is well defined by the nomenclature (e.g., Peninsular Arch and South Florida basin); 3) the names are consistent for genetically related Mesozoic features in the region (e.g., the Conecuh and Apalachicola Embayments; and 4) the nomenclature is well established in state and federal literature as well as in the oil and gas industry. Admittedly, revision of some of the nomenclature would give a more accurate lithotectonic description of these features. For example, the "embayments" might be better defined if called "grabens." However, due to the need for consistency and to avoid further confusion by adding to the list, no new names are introduced. The Florida basement nomenclature used in this report should be used in subsequent publications. All structural features shown on the Florida basement map (Figure 12) are discussed in the following text from northwest to southeast.

In the Florida panhandle, the Conecuh Embayment, the Chattahoochee Arch and the Apalachicola Embayment are thought to be a graben-horst-graben sequence formed during Mesozoic rifting (Miller, 1982). These grabens contain Triassic Newark Group equivalent sediments (Eagle Mills Formation) and Jurassic sedimentary rocks interlayered or cut by basalts and diabase. Contact metamorphic aureoles are associated with the intrusions (Milton, 1972). In the above context, the horst is represented by the Chattahoochee Arch, which is an uplifted block consisting of Triassic and Paleozoic sediments overlying an Upper Precambrian - Lower Cambrian igneous terrane. Arden (1974) quantified the extent of Paleozoic sediments in the area with seismic data, identified the block as the western limit of the north-west trending Paleozoic Suwannee basin and suggested the presence of a thick Triassic section in the uplifted block. More recently, however, Arden (1987, written communication) notes that most of the sediments near the arch are Paleozoic (based on fossil evidence) rather than the uppermost part being predominantly Triassic, as previously reported (Arden, 1974). In contrast, lithologic descriptions and well-log interpretations suggest there is no Triassic in this area (G. Winston, personal communication, 1988).

The Suwannee basin sediments generally consist of Ordovician quartzitic sandstones and Silurian to Devonian black shales and siltstones, some of which are red and may be confused with Triassic red beds. Paleontological evidence constrains the age of these Paleozoic rocks and suggest an early Paleozoic connection of Florida to Africa and South America (Gondwana) (Cramer, 1973; Pojeta et al., 1976). More recent paleomagnetic (Opdyke et al., 1987) and geochronologic evidence (Opdyke et al., 1987; Dallmeyer, 1987) support this conclusion.

Felsic igneous (and metamorphic ?) rocks underlying the Suwannee sediments are directly below the top of the basement surface in the Florida panhandle. These crystalline rocks may belong to the same terrane as that of central Florida (Chowns and Williams, 1983). An unpublished K-Ar (feldspar) age determination of 709 ± 25 Ma from a granodiorite in Gulf County (Earth Resource Consultants, Inc., 1981; W-12509, P-746), however, suggests that the panhandle igneous complex may be older than that of central Florida.

The northeast-trending Apalachicola Embayment lies east of the Chattahoochee Arch. Corehole data indicate that the Apalachicola Embayment contains secondary horst blocks (Barnett, 1975). The Triassic sediments located east of the Apalachicola Embayment (those centered on Taylor County; Barnett, 1975) may be erosional remnants of a separate basin or the preserved eastern extension of the Embayment separated by a secondary horst block. In contrast, if the red beds beneath Taylor County are Paleozoic rather than Mesozoic as suggested by Winston (1987, personal communication) then they represent part of the Suwannee basin.

Palynology of sedimentary rocks (written communication, D.L. Martin, Sohio, 1985) and radiometric data from basalts (Table 1) sampled from the Gainesville 707 offshore corehole (Figure 1, corehole location number 3) indicate that the Triassic graben(?) of the Apalachicola Embayment and/or Taylor County Mesozoic(?) sediments extend at least 40 miles into the Gulf of Mexico. Ironically, overlying the basalts at 12,440 feet in this corehole, rhyolitic cuttings yield a Rb-Sr whole rock age of 576 ± 20 Ma (Sohio, 1986). These have been interpreted to represent coarse clastic deposits "whose source is an uppermost Precambrian to lowest Cambrian terrane of acid volcanics and fine grained granites" (written com-

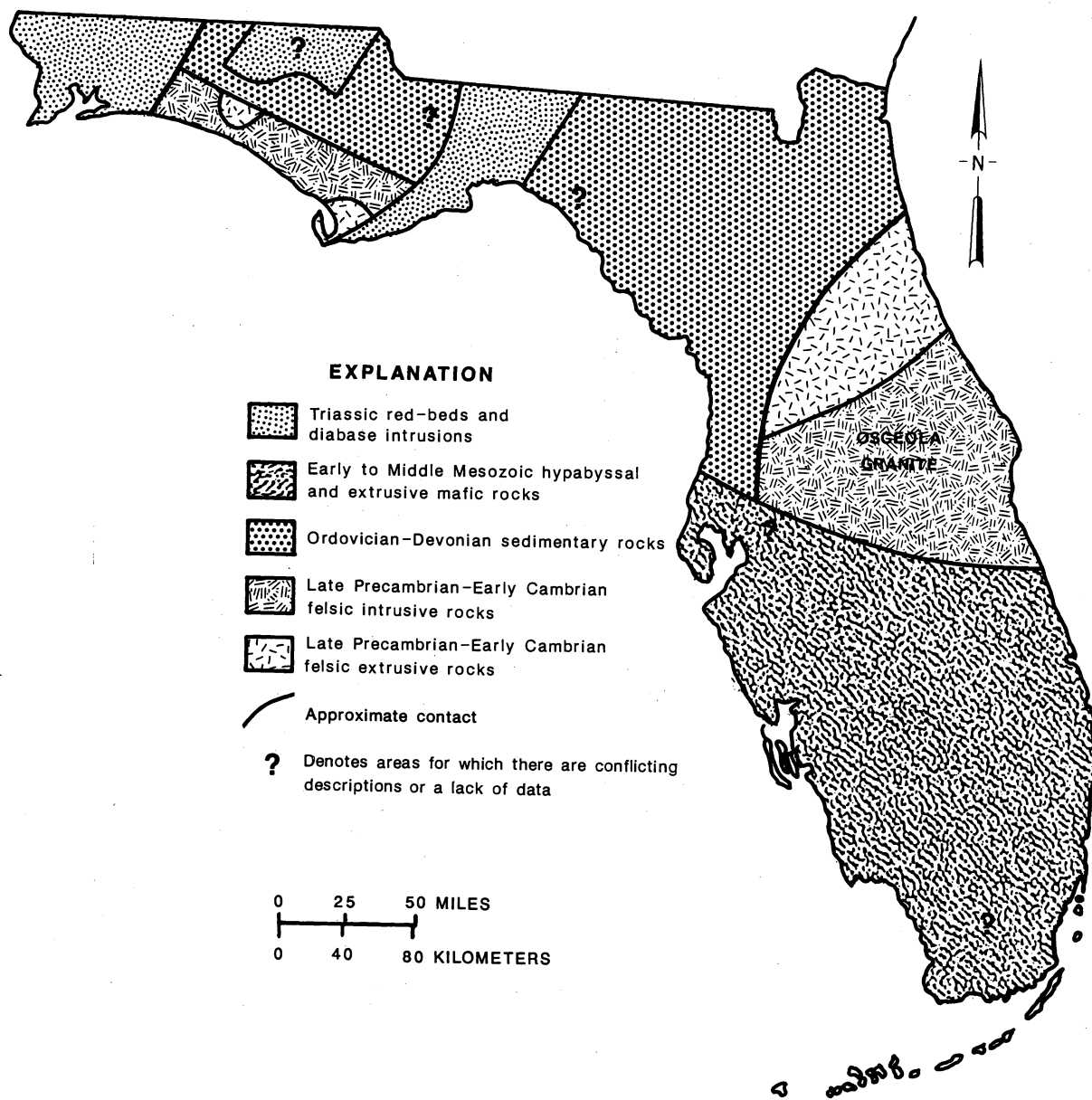


Figure 11. Lithology of the pre-Middle Jurassic Florida basement surface.

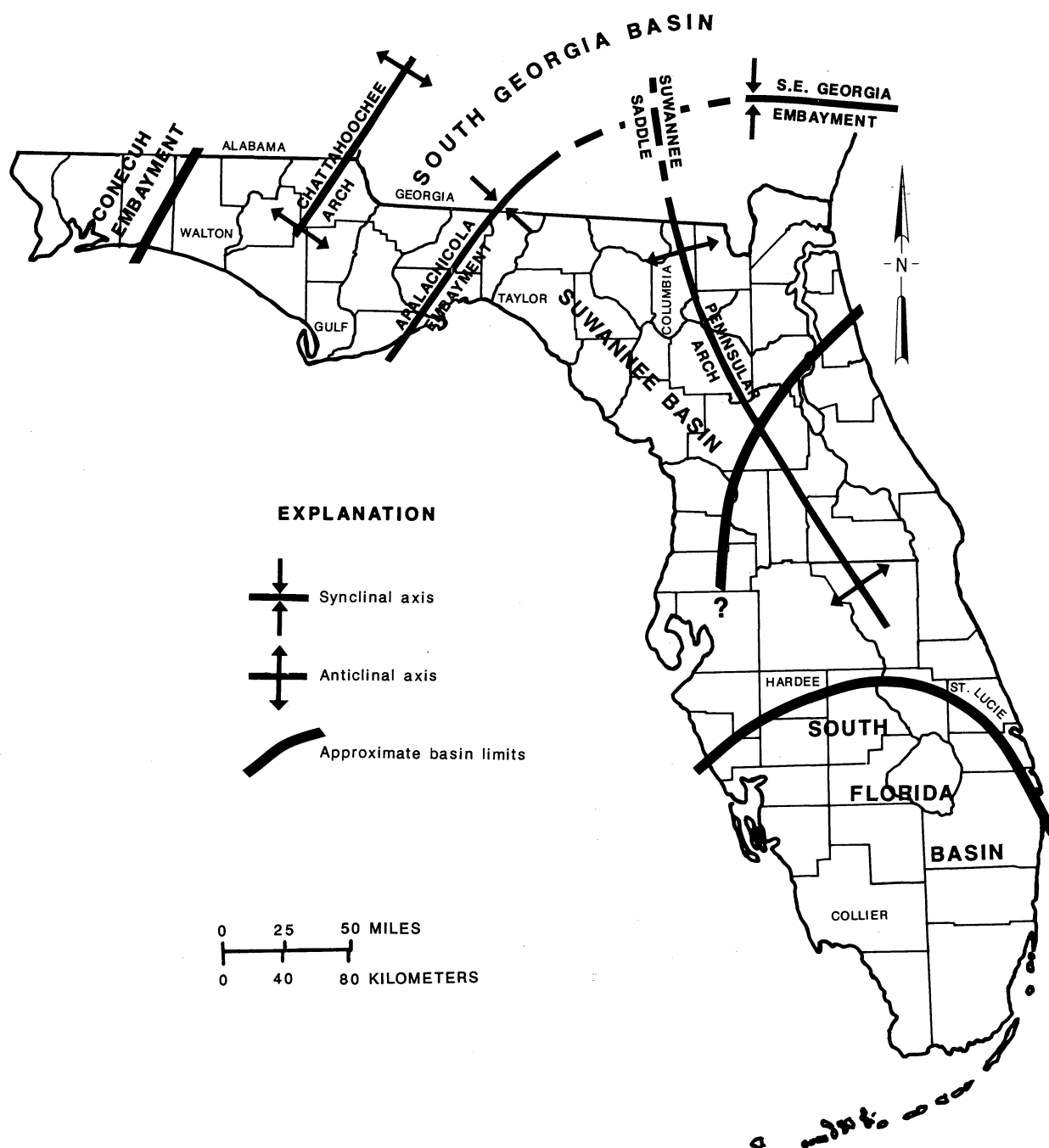


Figure 12. Florida basement pre-Middle Jurassic tectonic features.

munication, A.L. Odom and R. Taylor, Sohio, 1986). An alternative data interpretation suggests that the aforementioned Triassic section is Paleozoic (G. Winston, personal communication, 1988).

The Apalachicola Embayment and smaller north Florida basins are successor basins within the Suwannee basin (Figure 12). On a more regional scale, the Apalachicola Embayment is the southwest extension of the larger South Georgia basin (Chowns and Williams, 1983). The eastern portion of the South Georgia basin consists of the Southeast Georgia Embayment. These two embayments are separated by the Suwannee Saddle, which is a northwestern extension of the Peninsular Arch. The Peninsular Arch is a positive feature containing upper Precambrian-Lower Cambrian continental crust overlain by Suwannee basin sediments. Intrusions of Mesozoic diabase as well as basalt flows are located within the Suwannee Basin sediments.

The southeastern subcrop limit of the Suwannee basin is bounded by a central Florida igneous complex. Barnett (1975) has subdivided the igneous terrane into a northern felsic volcanic and southern felsic to intermediate plutonic province, the latter of which is termed the Osceola Granite (Chowns and Williams, 1983). Radiometric data indicate that the Osceola Granite is Middle Cambrian in age (approx. 527 Ma, Bass, 1969; 527-534 Ma, Dallmeyer et al., 1987). Both Chowns and Williams (1983) and Dallmeyer et al. (1987) propose that these older crystalline basement rocks are part of the Pan-African Rokelide fold belt. A core from St. Lucie County (Figure 1, corehole location number 31), south of the Osceola Granite, is reported to contain Pan-African metamorphic rocks overlain by a felsic igneous sequence and Mesozoic (?) basalt (Bass, 1969; Chowns and Williams, 1983). Bass (1969) reports an approximate age of 530 Ma (Rb-Sr, biotite) for dioritic gneiss in this core.

The South Florida basin shown on Figure 12 is a Mesozoic stratigraphically defined basin centered in the Gulf of Mexico. The portion of the basin located on Peninsular Florida is approximately the northeastern third of the entire basin. Within this portion of the basin, Jurassic and younger sediments overlie a predominantly mafic volcanic basement (Winston, 1971; Barnett, 1975). Cuttings from a deep oil test well in Collier County (Exxon, W-15095, P-1042), however, reveal felsic igneous rock directly below the top of the basement surface at the depth of approximately 17,000 feet. An unpublished K-Ar, whole rock age determination from the cuttings suggests Middle Jurassic emplacement (164 ± 7 Ma, Amoco, 1985). Also in Collier County, a "rhyolite porphyry" in Bass well No. 12-2 (W-12838, P-778) has been dated at 189 ± 5 Ma (Rb-Sr whole rock, Shell Oil, 1978). Radiometric dating of basalts in the basin indicates that their emplacement was during the Early to Middle Jurassic (Table 1). Note, however, that caution should be used when interpreting any of these data (see "Age" section in Part One of this report).

Since the early comprehensive works of Applin (1951) and Barnett (1975), numerous studies have focused on geophysical, radiometric, paleontologic, petrologic and tectonic aspects of the deep subsurface of Florida. Although new data and theories arise, several unanswered questions and occasional conflicting interpretations still exist. Additional work in all of the above disciplines is needed in order to further refine our knowledge of the Florida Basement.

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