# GEOTHERMAL GRADIENTS IN FLORIDA AND SOUTHERN GEORGIA

G. M. GRIFFIN
Department of Geology
University of South Florida
Tampa, Florida

P. A. TEDRICK
Department of Geology
University of South Florida
Tampa, Florida

D. A. REEL
Department of Geology
University of South Florida
Tampa Florida

J. P. MANKER
Department of Geology
University of South Florida
Tampa, Florida

## ABSTRACT

Bottom hole temperatures from electric log surveys were collected from all non-confidential oil tests that recorded temperature data. These data include points from 287 wells in Florida and 33 in Georgia. Computed gradients were compiled into county averages, and a preliminary geothermal gradient map was drawn.

Peninsular Florida, south of a NE-SW trending zone through Taylor and Nassau Counties, is characterized by gradients generally less than 1.0 degree (F)/100 feet. Northern Florida and southern Georgia are characterized by gradients that generally exceed 1.0 degree (F)/100 feet. A weak and questionable increase in gradient may occur over the Sunniland Field in southwest Florida.

The observed NE-SW geothermal trend parallels the Appalachian Mountain belt and coincides with known magnetic and gravity features of the area. It also parallels the migrating Cretaceous to Recent clastic-nonclastic boundary in northern Florida.



## INTRODUCTION

Geothermal gradients, based mainly on bottom hole temperatures, have been computed for 287 oil tests in Florida and 33 in Georgia. These data include essentially all oil tests in the two states in which temperatures were recorded and not considered as confidential by the operators. The present work is part of a regional study of geothermal relationships in the southeastern states and will ultimately be included in the Geothermal Survey of North America, a special project of the American Association of Petroleum Geologists.

Interest in the data among petroleum geologists has prompted publication here of a preliminary map for Florida and Georgia. Logs for South Carolina and North Carolina are still being collected, and the data are not presently available. We have also initiated a more detailed study of a weak and questionable geothermal anomaly that may be related to the Sunniland-Felda-Forty Mile Bend oil field trend in South Florida.

## ACKNOWLEDGMENTS

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## PREVIOUS STUDIES

Aside from two interesting articles by F. A. Kohout (1965, 1967) that were directed primarily toward an understanding of ground water flow, no geothermal survey of Florida has been published. Kohout's study included temperature surveys of six wells. He concluded that temperatures in the Floridan Aquifer (depth range approximately 1000 to 3000 feet below sea level) may be significantly reduced by hydrologic interchange with the 44° F ocean bottom waters of the nearby Florida Straits and Gulf of Mexico. Generally, the discontinuous nature of the BHT electric log values used in our survey has prevented examination of this cooling phenomenon, and it has been of necessity neglected here.

## COLLECTION AND QUALITY OF DATA

Since approximately 1943 electric log headings have included bottom hole temperature (BHT) or maximum temperature readings. These values are measured with a maximum reading thermometer during standard electric log runs and are generally assumed to measure the temperature of the bottom of the borehole. Normally, log runs are made at several different depths during drilling so that a plot of temperature versus depth can be constructed. The overall geothermal gradient is obtained easily from this plot and listed as degrees (F) increase in temperature per 100 feet of depth increase. Schoeppel (1966) used a similar technique in his study of gradients in Oklahoma.

The technique, although simple in theory, introduces considerable uncertainty and frustration in practice, mainly because the quality of the data varies greatly and its reliability is usually impossible to determine. Schoeppel (1966) has elaborated on the causes of these uncertainties, and everyone who has attempted to use BHT gradients is aware of the poor quality of much of the data. Temperature measurement is usually quite secondary to other logging matters, and it is apparent that much BHT data is based on estimates from measurements in previous wells or assumptions as to the average regional gradient. Few of the potential errors are systematic; one that is systematic is the general tendency for BHT readings to be lower than the true temperature values at depth. This variation is caused by the ventilating and cooling effect of the drilling fluid in the well, and it is generally of unknown magnitude. Thus, geothermal gradients plotted from BHT readings are not exact and precise pieces of scientific data, and anomalies must be considered as suspect unless supported by an abundance of data.

However, in spite of the rather poor quality of the data, BHT readings constitute the *only* abundant source of subsurface temperature data for most of the world. This is especially true in Florida and Georgia where data from production testing is almost non-existant. It is, of course, in such virgin areas that future oil and gas reserves must be sought, and data that is scientifically unsatisfying must often be used.

## GEOTHERMAL TRENDS IN FLORIDA AND GEORGIA

Despite the paucity of data several broad trends are indicated on the gradient map (Figure 1) which is based on average gradients in each county for which there are available data. The Florida peninsula exhibits gradients usually less than 1° F/100 feet. Generally the best quality data points in this area indicate a gradient near 0.86° F/100 feet, but unexplicable variations occur in some wells.

Northward of a NE-SW trending transition zone from approximately Nassau County to Taylor County, the gradients generally increase to values greater than 1.0° F/100 feet. The definition of this transition zone is obviously arbitrary, and the dashed lines on Figure 1 should be considered as trends rather than as rigid boundaries. However, based on the available data, the trend of the transition from relatively low to relatively high gradients is considered as geologically significant.

In northwest Florida and Georgia, gradients in the range of 1.1 to 1.5 are generally recorded, with maxima of 2.44 and 2.55 in two wells in central Georgia. These are the highest gradients known to us in the coastal plains of Georgia and Florida.

One other area in which a possible anomaly was noted is along the trend of the Sunniland–Felda–Forty Mile Bend oil fields in southwest Florida. The validity and significance of this possible anomaly is being investigated further. The county average map (Fig. 1) tends to average-out the anomaly, but some wells within the circled area, especially over Sunniland Field, have gradients of 1.3 to 1.6, which appear significantly higher than the surrounding area. We do not care to speculate on the cause of this anomaly until we have substantiated it and completed our study in that area.

## SPECULATIONS CONCERNING THE NE-SW GEOTHERMAL TREND

The observed NE-SW trending iso-gradient zones parallel a number of other regional geological/geophysical trends. Most obviously, the geothermal trend parallels the Appalachian Mountain belt, which is reflected in much of the tectonic fabric of the southeastern states.

The regional magnetic map published by King (1959) and extended westward into the Gulf of Mexico by Gough (1967) shows striking trend-parallelism with the geothermal map. In particular, the NE-SW magnetic trend that is suggested as due to a pre-Mesozoic volcanic belt parallels the geothermal trend, and the northern boundary of the volcanic belt is close to the southern dashed line of the transitional area shown on Figure 1. Also, a NW-SE trending negative magnetic anomaly across SW Florida parallels and is close to the suggested geothermal anomaly in the Sunniland Field vicinity.

The regional Bouguer anomaly gravity map of Lyons (1950) also shows parallelism with the NE-SW geothermal trend. However, a later free-air gravity map of the offshore Gulf area by Dehlinger and Jones (1963) fails to show a westward continuation of the gravity anomaly.

Stratigraphically, the most obvious correlative feature is the parallelism between the clastic-nonclastic boundary and the geothermal trend (Fig. 2). Applin (1951) has shown the clastic-nonclastic boundary for the lower Cretaceous, and Chen (1965) has indicated it for the upper Cretaceous through upper Eocene; data from these two sources were used to construct Figure 2. The boundary has tended to shift westward with time and still persists in Recent sediments in the general area southwest of Cape San Blas. Migration of the boundary has left an intertounging sequence of clastics and nonclastics (mainly limestone, dolomite, and anhydrite) in the northern part of peninsular Florida in the transitional geothermal area.

Thus, the geothermal trends parallel a number of known geological and geophysical trends in the area. It is very likely that all of these features are interrelated. The observed geothermal relations suggest one of two possibilities: Either: (1) the thermal conductivity of rocks in the carbonate-evaporite province of peninsular Florida is greater than in the sand-shale province of northern Florida and southern Georgia; or (2) there is a significant difference in the quantity of geothermal energy supplied to the two areas. At present, possibility (1) seems more likely but cannot be substantiated quantitatively until the relative thermal transmissibility of the actual rock columns in Florida has been determined.

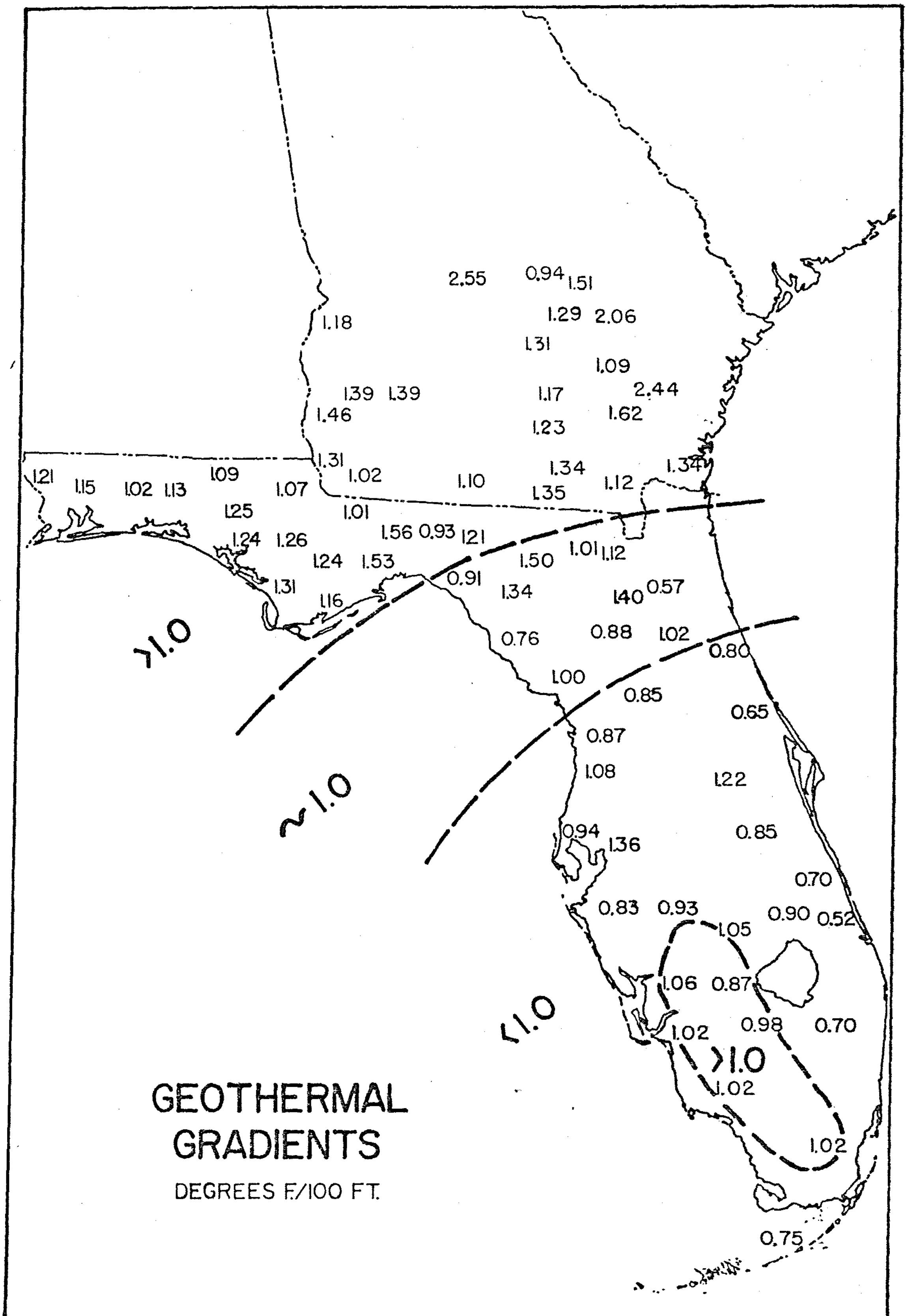


Figure 1. Preliminary map of geothermal gradients in Florida and Southern Georgia. Averages of all thermal data points within each county are shown. Dashed lines indicate trend of gradient values from < 1.0 in southern Florida to > 1.0 in northern Florida, with a transition zone between. A possible weak thermal anomaly over the Sunniland Field trend is indicated in southwest Florida.

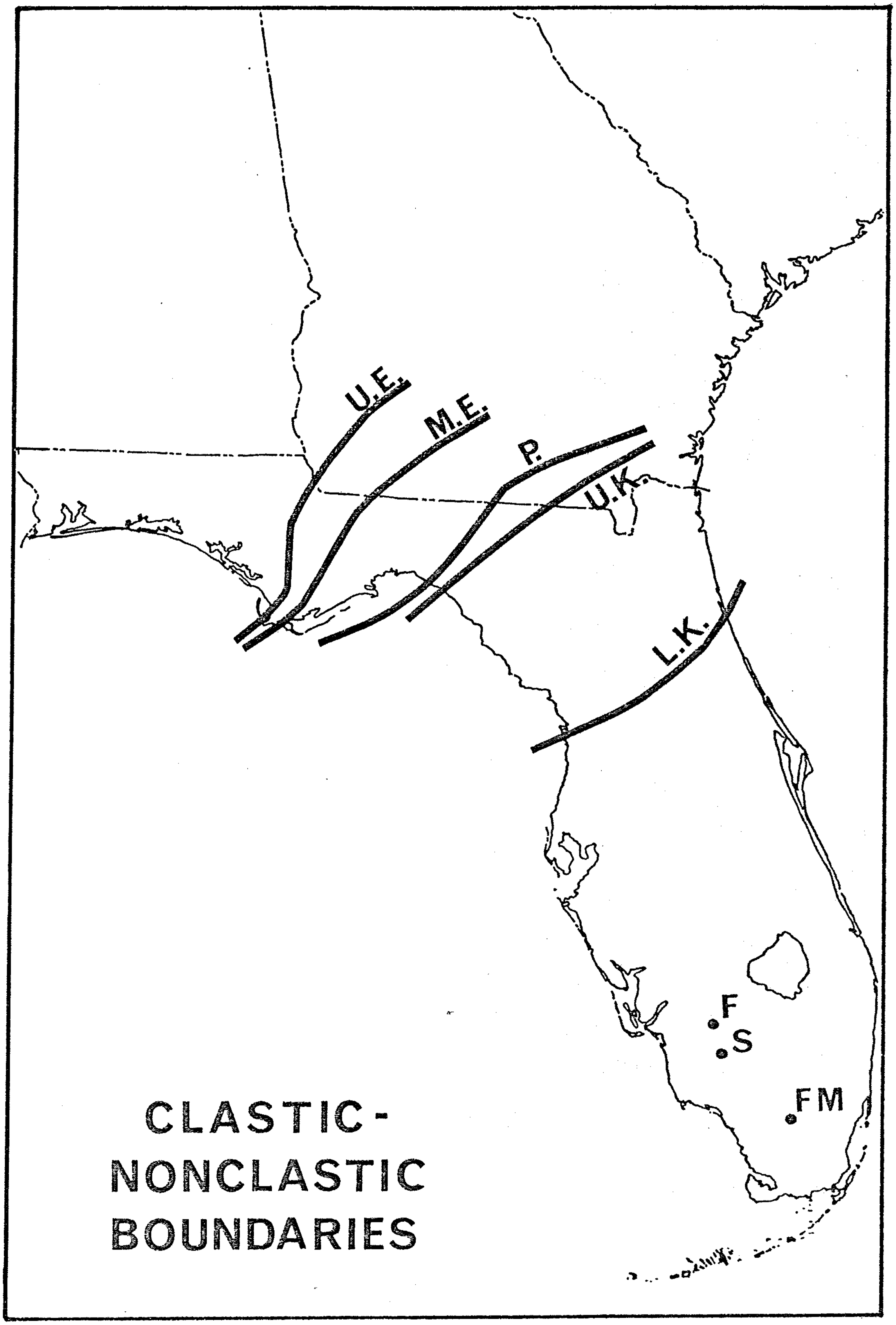


Figure 2. Position of the clastic-nonclastic sediment boundary. L. K. (lower Cretaceous) after Applin (1952); U. K. (upper Cretaceous), P. (Paleocene), M. E. (middle Eocene), and U. E. (upper Eocene) after Chen (1965). Oil fields are indicated: F=Felda Field; S=Sunniland Field; FM=Forty Mile Bend Field.

## REFERENCES CITED

Applin, P. L., 1952, Sedimentary volumes in Gulf Coastal Plain of the United States and Mexico, Part I: Volume of Mesozoic sediments in Florida and Georgia: Am. Assoc. Petroleum Geol. Bull., vol. 63, pp. 1159-1164.

Chen, C. S., 1965, The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida: Fla. Geol. Surv. Bull. 45, 105 pp.

Dehlinger, Peter, and R. R. Jones, 1965, Free-air gravity anomaly map of the Gulf of Mexico and its tectonic implications, 1963 edition: Geophys., vol. 30, pp. 102-110.

Gough, D. I., 1967, Magnetic anomalies and crustal structure in the eastern Gulf of Mexico: Am. Assoc. Petroleum Geol. Bull., vol. 51, pp. 200-211.

King, E. R., 1959, Regional magnetic map of Florida: Am. Assoc. Petroleum Geol. Bull., vol. 43, pp. 2844-2854.

Kohout, F. A., 1965, A hypothesis concerning cyclic flow of salt water related to geothermal heating in the Floridan aquifer: Trans. N. Y. Acad. Sci., ser. II, vol. 28, pp. 249-271.

_______ 1967, Ground-water flow and the geothermal regime of the Floridan Plateau: Gulf Coast Assoc. Geol. Soc. Trans., vol. 17, pp. 339-354.

Lyons, P. L., 1950, A gravity map of the United States: Tulsa Geol. Soc. Digest, vol. 18, pp. 33-43.

Schoeppel, R. J. and S. Gillarranz, 1966, Use of well log temperatures to evaluate regional geothermal gradients: J. Petroleum Technology, June 1966, pp. 667-673.