POTENTIALLY PETROLIFEROUS TRENDS IN FLORIDA AS DEFINED BY GEOTHERMAL GRADIENTS

David A. Reel[1] and George M. Griffin[2]
Baton Rouge, La. 70803 Gainesville, Florida 32601

ABSTRACT

A newly constructed geothermal gradient map of Florida suggests areas with high petroleum potential and the thickness of the potentially petroliferous section. The base of the "potential section" is defined by the depth of the basement and the top is defined by the depth at which the minimum temperature exists for petroleum maturation. Based on previous studies this upper limit is assumed to coincide with the 221°F isotherm depth. A "potential section" map has been prepared which includes all of the presently productive fields and new discoveries within favorable areas. Locations of thick sediment sections of proper temperature for oil occurrence are: the Western Panhandle, a small area of the central Panhandle, and the extreme southwestern part of the peninsula. Over most of central and north Florida and in the southernmost Keys the basement may be penetrated before encountering the requisite minimum temperature for petroleum maturation. Tests in these areas run a higher probability of being barren.

INTRODUCTION

Within the state of Florida over 300 oil tests have been drilled. Most of these tests have been dry. Figure 1 shows the area of study and oil productive areas. In South Florida several small fields have been discovered in the Sunniland Limestone of Lower Cretaceous age and increased exploration is underway. Jay Field, Santa Rosa County, was discovered in 1970 and produces from the Jurassic Smackover Formation. It is the only field in North Florida and has resulted in much exploration. Nevertheless, most of the state remains barren.

The reason most of Florida has failed to produce commercial oil or gas has not been explained satisfactorally. Explanations include: the difficulty of seismic exploration, lack of effective porosity and permeability, and lack of source beds. This study suggests that if the subsurface transformation of a random assemblage of organic molecules into petroleum-like molecules is temperature dependent, then the apparent oil and gas barrenness of most of the state may result from the lack of sufficient subsurface temperature for the requisite organic transformation. That is, over much of the state, the sedimentary section overlying the basement is too cool for the thermal maturation of hydrocarbons.

GEOTHERMAL GRADIENT VARIATIONS

Geothermal gradients calculated from temperature and depth values recorded on electric logs have been compiled and averaged for each drilled township in Florida and South Georgia (Reel, 1970). Geothermal gradients determined from electric logs are not universally accepted as precise. Poor, old well control, influence of drilling fluid circulation, and biased location affect the quality of the data. However, at the present time, electric logs are the only source of subsurface temperature information for Florida.

Figure 2 is a contour map of average township geothermal gradients. It suggests several important variations. On the whole, average geothermal gradients are higher in North Florida than in South Florida. This trend was noted in a preliminary study by Griffin, *et al*, 1969. This variation is attributed to greater proximity to a heat source in the crust and/or a higher temperature of the source. Similarly, the gradient high in the center of the Florida Peninsula (Polk County area) may be related to the shallowness of the basement along the Peninsula Arch and a subsurface belt of relatively conductive and dense pre-Mesozoic volcanic rocks that crosses central Peninsula Florida (Gough, 1967). These volcanic rocks may transmit heat from the source more effectively than do the surrounding sedimentary rocks, and thus provide a potential localization of heat.

Another area of interest is the northwest-southeast Sunniland oil field trend in South Florida. A local geothermal gradient high is indicated in the Sunniland and Felda field area and also in the abandoned Forty Mile Bend field. The Sunniland field, located on an anticlinal structure, has individual wells with gradients as high as 1.5°F/100 feet. The cause of the anomaly may be related to the Sunniland structure but, more likely, the high gradients are produced by the presence of the petroleum itself. Slow spontaneous oxidation of oil may create a local heat source of small but sufficient magnitude to increase the geothermal gradient in the field area. The ability of petroleum oxidation to produce local subsurface temperature anomalies has been recognized in the U. S. S. R. (Mekhtiev and Aliev, 1968; Makarenko, Polak, and Smirnov, 1968).

PETROLIFEROUS TRENDS — GEOTHERMAL GRADIENT RELATIONSHIPS

Burst (1969) suggested that thermally induced clay mineral dehydration is related directly to the flushing of hydrocarbons from source beds and their transport into reservoirs. He showed that it is possible to relate the minimum depth of liquid petroleum production to the depth at which the second stage of dehydration

[1]Louisiana State University.
[2]University of Florida.

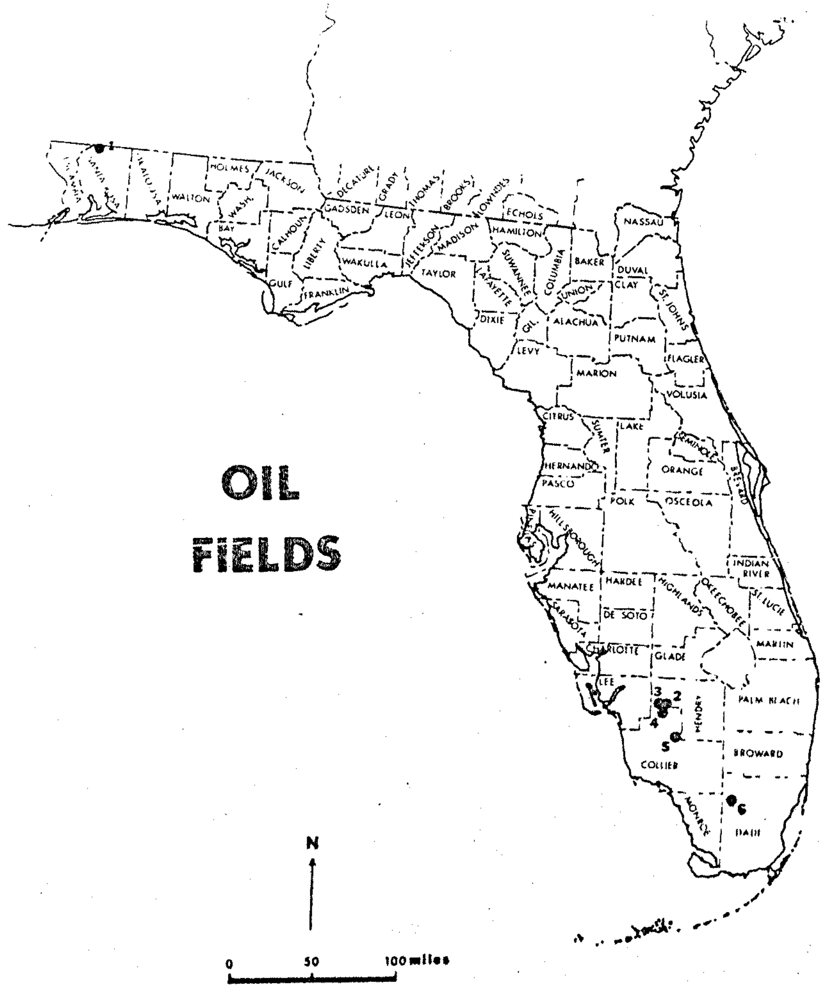

FIGURE 1—Index map of Florida showing county lines and location of oil producing areas as of July, 1970; Jay field (1), Felda field (2), West Felda field (3), Lake Trafford field (4), Sunniland field (5), and Forty Mile Bend field (6).

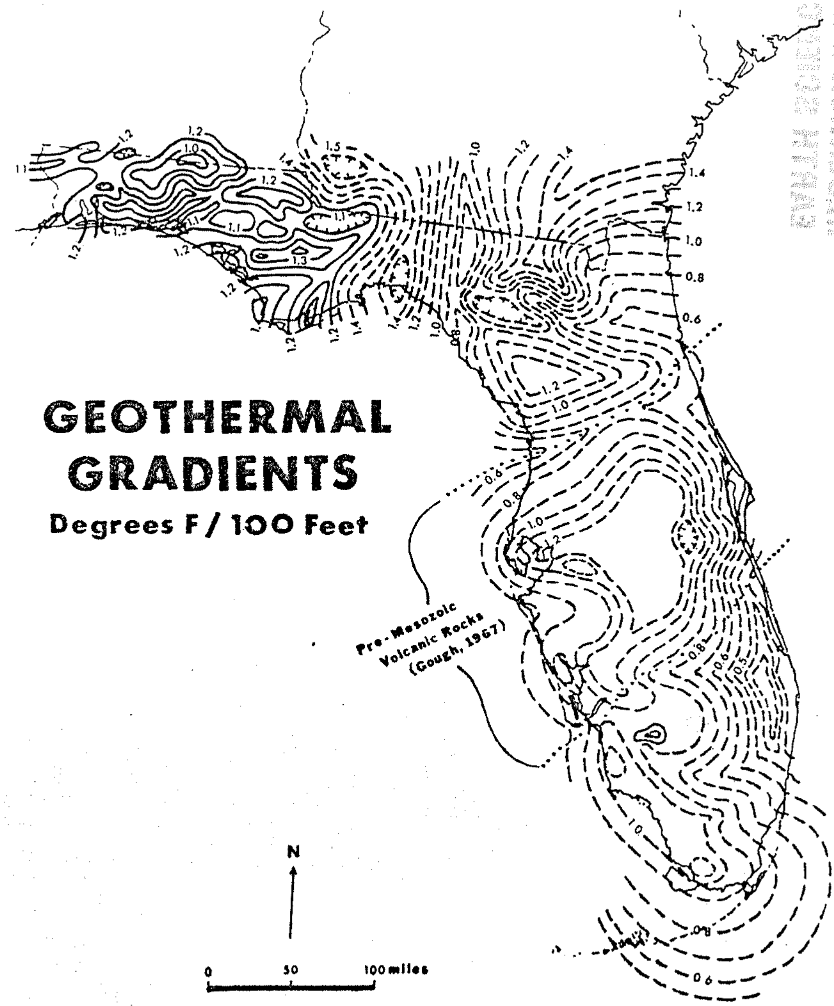

FIGURE 2—Contour map of township averages of geothermal gradients in Florida and south Georgia.

and water release occurs in montmorillonite. Burst indicates clay diagenesis is essentially a temperature controlled process and can be interpreted best in terms of burial temperature rather than burial depth. He tabulated the minimum temperatures for petroleum production in 5,368 oil reservoirs in the central and western Gulf Coast. The temperatures range from approximately 221°F to 260°F and are considered by Burst to be closely related to the temperature of oil maturation in that area.

For this study, it was assumed that Burst's 221°F value represents the minimum temperature required for the formation of oil and that the same temperature limits apply irrespective of lithology. With this assumption, the geothermal gradient map (Fig. 2), and the average surface temperature, the depth to a temperature of 221°F was calculated for each township using available temperature data. A contour map indicating the depth of the 221°F isotherm is shown on Figure 3. The map represents the hypothetical shallowest depth at which *in situ* liquid hydrocarbons should normally be expected provided extensive lateral or vertical migration has not occurred.

Figure 3 suggests that the 221°F isotherm depth varies considerably over the state. In northwest Florida the 221°F isotherm generally occurs between 8,000 and 16,000 feet; in the Peninsula, between 10,000 and 24,000 feet; and in the southernmost Keys it may increase to over 30,000 feet. The shallower 221°F isotherm depths in the Panhandle and elsewhere result from steeper geothermal gradients in those places, and the great depth of the isotherm in the Keys is due to a very low geothermal gradient. The isotherm pattern would be generally the same if some other isotherm were plotted.

Assuming the contours of Figure 3 approximate the shallowest depths of potential liquid hydrocarbon formation, the important question is whether it is possible to drill to these depths before encountering the "basement" complex. The basement generally is considered to be pre-Mesozoic sediments and/or volcanic and instrusive igneous rocks. It has not produced hydrocarbons anywhere in the Gulf Coast, and its top usually is considered the practical limiting depth for petroleum production, although production may be found in some of the Paleozoic sediments of northern Florida. The depth to the top of the "basement" complex is indicated on Figure 4. The depths agree very well with other published recordings of pre-Mesozoic basement depths in Florida (Applin, 1951). By subtracting the depth of the 221°F isotherm (representing the shallowest expected depth of *in situ* liquid hydrocarbon occurrence) from the depth of the "basement" complex (the deepest expected producing depth), the thickness of section in which liquid hydrocarbons will most likely occur can be derived. These values are contoured on Figure 5.

Some interesting speculations regarding oil potential can be derived from Figure 5. The basement surface plunges toward the southwest (Fig. 4) resulting in a Mesozoic and Cenozoic sediment thickness greater than 25,000 feet and implying great thickness of potentially hydrocarbon bearing section. Figure 5, however, suggests that for much of this area, especially in the southern Keys, the requisite temperature for liquid hydrocarbons may not be reached before penetrating the basement. Therefore, potential oil bearing section may not exist in these areas.

The entire central part of Florida, as well as most of South Georgia—North Florida, are indicated as being unfavorable for liquid hydrocarbon formation. In these areas, the sedimentary section is too thin for the requisite 221°F temperature to be encountered above the "basement."

Areas indicated in Figure 5 to contain thick sediment sections of the proper temperature for oil occurrence contain all of the known oil producing areas in Florida. Three areas of most promising oil potential are indicated. The first area is in the western part of the panhandle, where the thickness of the potential section reaches nearly 14,000 feet and probably increases offshore toward the southwest. Jay field is in the northern part of this area. The discovery well produced over 1,700 barrels of oil per day on test. Figure 5 predicts 7,000 feet of potential section at Jay, and Figure 3 suggests the 221°F isotherm should occur at a depth of 13,200 feet. Actual production was established at 15,500 feet. Based on the apparent local gradient of 1.15°F/100 feet, a temperature of 246°F exists at the producing depth. This value is well within the 221-260°F range suggested by Burst for liquid hydrocarbon production. Figure 5 suggests that a large area of the panhandle west of Apalachicola Bay is relatively favorable. The most promising part of this area is in parts of Escambia, Santa Rosa, Oklaloosa, and Walton Counties, and offshore as far as Cape San Blas.

A potential second area is much smaller in area and so far without production. It extends northeast from Franklin, Wakulla, and Taylor Counties, through parts of Leon, Madison, Lafayette, Suwannee, and Hamilton Counties, and into Echols County, Georgia. A number of oil shows have been encountered in this area, but no commercial production has yet been established. This area is poorly defined because of limited drilling, and it may be larger than indicated. As shown in Figure 5, the thickness of the potential section is relatively small when compared to the other two potential areas.

A third area of potential production is in the south Florida structural basin in the extreme southwestern part of the peninsula. This area includes Sunniland, Felda, West Felda, Lake Trafford, and Forty Mile Bend fields (Fig. 1), from which came all of the commercial production in Florida prior to the 1970 discovery at Jay. Geothermal relationships suggest that the potentially best parts of the basin have not been tested adequately. The favorable area includes large parts of Monroe, Dade, Collier, Hendry, Lee, and Charlotte Counties. Parts of the surrounding area, such as Broward, De Soto, and Sarasota Counties have not been drilled adequately to definitely exclude them. The favorable band may well extend farther offshore to the southwest or east, because no wells have been drilled to define the seaward limits. The area with the highest exploration potential, containing more than 12,000 feet of sediment in the acceptable temperature range, lies in a NW-SE band offshore from Collier and Monroe Counties.

In summary, it must be stressed that the usual factors controlling oil accumulation, such as favorable

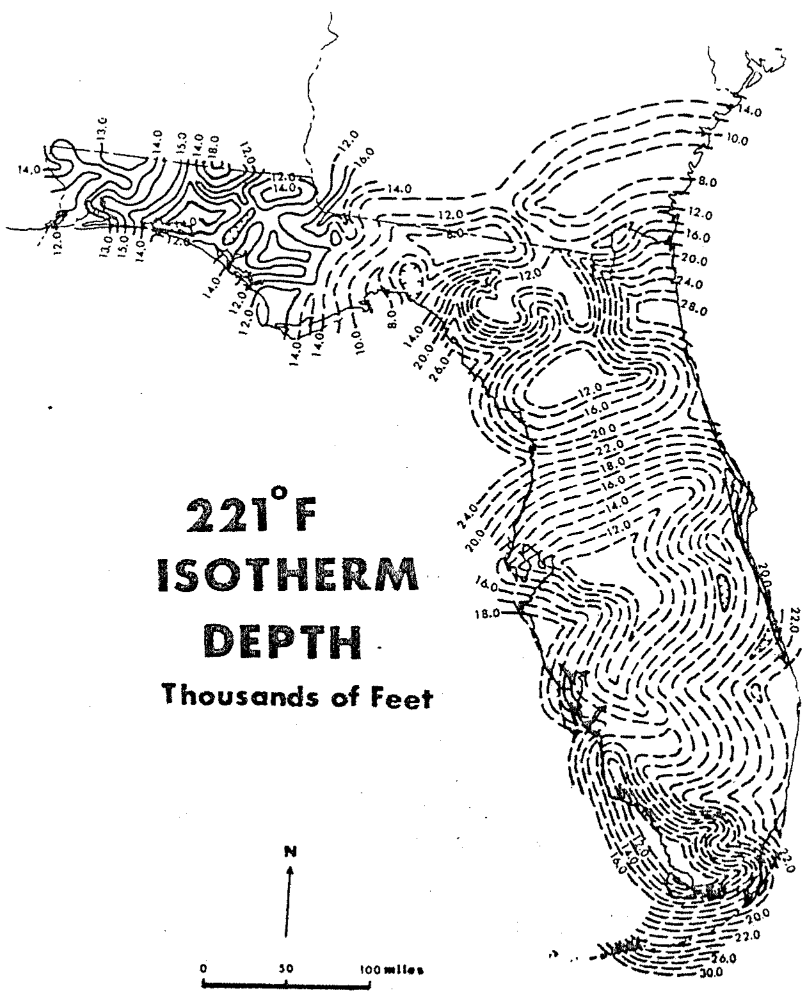

FIGURE 3—Contour map indicating the depth to the 221°F isotherm. Depths are calculated from township geothermal gradients of Figure 2.

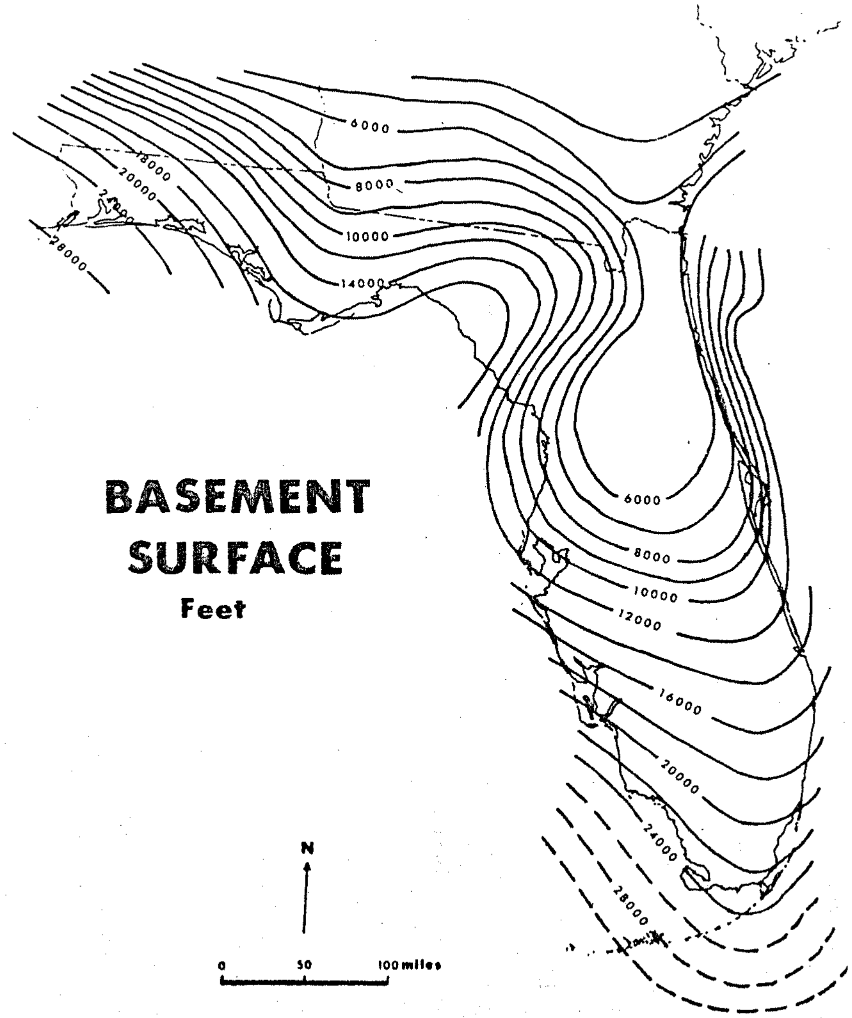

FIGURE 4—Contour map indicating depth to the "basement" complex of pre-Mesozoic sediments and/or volcanic and intrusive igneous rocks in Florida (after Kinney, 1967).

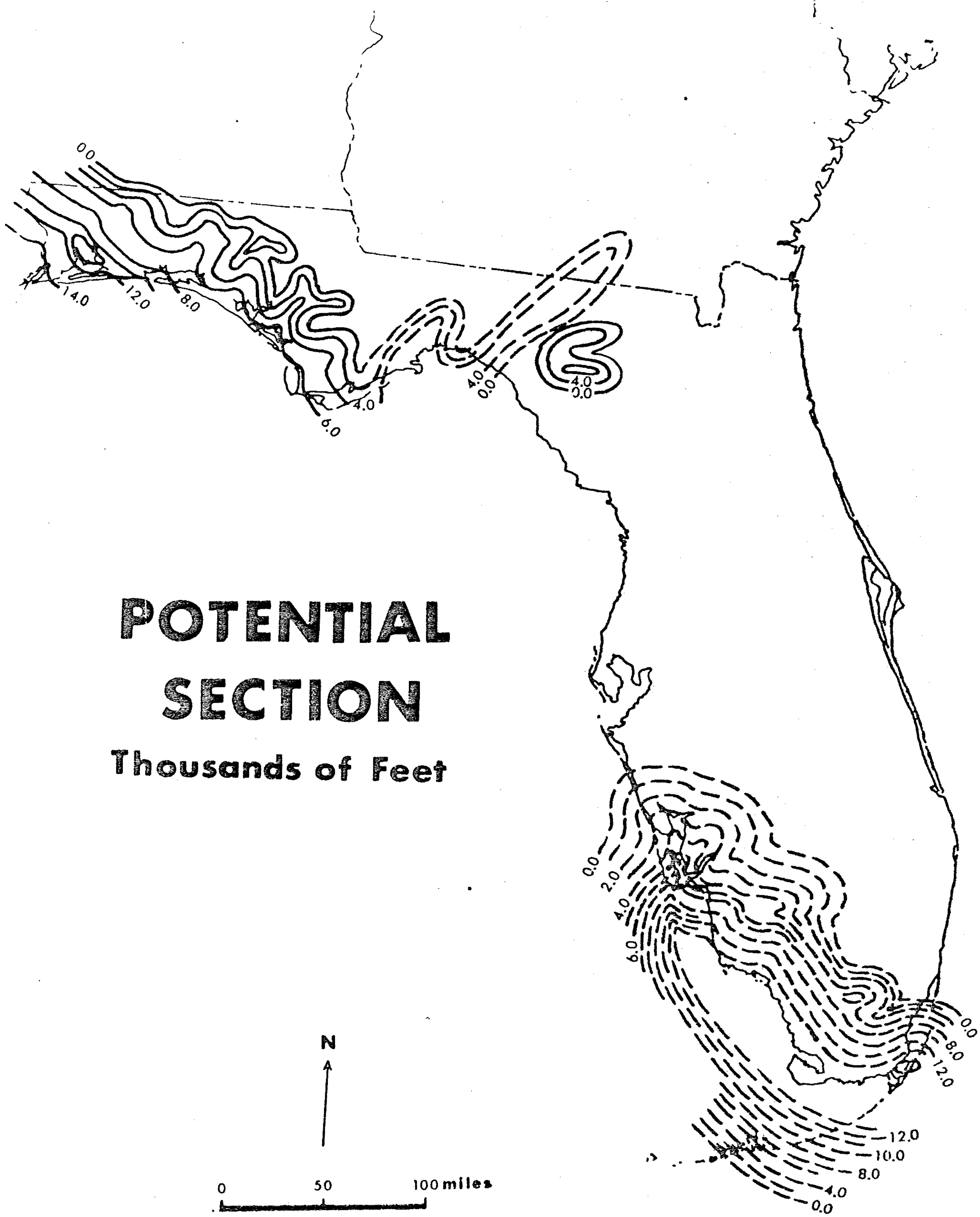

FIGURE 5—Thickness of potential section above the "basement" complex. Generation of liquid hydrocarbons will most likely occur in the contoured areas.

traps, migration paths, and source beds are necessary. Nevertheless, good correlation between presently known geothermal relationships and known oil occurrences strongly suggests that earth temperatures should definitely be considered in petroleum exploration programs in sparsely drilled areas such as Florida.

REFERENCES

Applin, P. L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjoining states: U. S. Geol. Survey Circ. 91, 28 p.

Burst, J. F., 1969, Diagenesis of Gulf Coast clayey sediments and its possible relation to petroleum migration: Am. Assoc. Petroleum Geologists Bull., v. 53, p. 73-93.

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

Griffin, G. M., P. A. Tedrick, D. A. Reel, and J. P. Manker, 1969, Geothermal gradients in Florida and southern Georgia: Gulf Coast Assoc. Geol. Soc. Trans., v. 19, p. 189-193.

Kinney, D. M. (ed.), 1967, Basement map of North America: Am. Assoc. Petroleum Geologists and U. S. Geol. Survey, Basement Rock Project Committee.

Makarenko, F. A., B. G. Polak, and J. B. Smirnov, 1968, Geothermal field on the U. S. S. R. territory: Trans. Internat. Geol. Cong., Session 23, v. 5, p. 67-73.

Mekhtiev, S. F., and S. A. Aliev, 1968, On some problems of geothermy in the Caucasus: Trans. Internat. Geol. Cong., Session 23, v. 5, p. 103-110.

Reel, D. A., 1970, Geothermal gradients and heat flow in Florida: unpublished Masters of Arts Thesis, University of South Florida, 66 p.