UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# HELIUM ANOMALY IN SURFICIAL DEPOSITS OF SOUTH FLORIDA-- POSSIBLE INDICATOR OF DEEP SUBSURFACE PETROLEUM OR SHALLOW URANIUM-ASSOCIATED PHOSPHATE DEPOSITS

by

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CONTENTS


| | Page |
|---|---|
| ABSTRACT | 1 |
| ACKNOWLEDGMENTS | 2 |
| INTRODUCTION | 3 |
| Purpose | 3 |
| Principle and justification of helium surveys | 3 |
| Location | 4 |
| Factors responsible for selecting oil-prospective area | 5 |
| SAMPLE COLLECTION AND ANALYTICAL PROCEDURES | 7 |
| RESULTS AND DISCUSSION | 8 |
| SUMMARY AND CONCLUSIONS | 12 |
| REFERENCES | 13 |


ILLUSTRATIONS


Fig. 1. Map showing areas of helium surveys, location of oil fields, and present Sunniland producing trend. Accompanying index map shows outline of South Florida basin. 6

Fig. 2. Location of helium surveys along traverses A-B-C-D-E and F-G-B-C-H-J-K made in the oil-prospective area near Immokalee in north-central Collier County, Florida. 9

Fig. 3. Plots of helium concentrations in ppb above baseline along traverses A-B-C-D-E and F-G-B-C-H-J-K, (fig. 2). 10

ABSTRACT

Helium surveys of soil gases were conducted over two areas in south Florida in order to test their utility in petroleum exploration. In the first survey, a small but positive helium anomaly (40-60 ppb above background) was detected over the Sunniland oil field indicating an association between the anomalous helium concentrations and the petroleum reservoir. The second survey was conducted in an unexplored, oil-prospective area. A relatively strong helium anomaly, with concentrations of 40 - 140 ppb above background, was discovered east of the town of Immokalee, Florida.

Two possible interpretations are offered: (1) The high helium concentrations reflect gas leakage from subsurface oil accumulations in Lower Cretaceous reservoirs, most likely from Sunniland and/or Fredericksburg 'B' carbonate rocks. (2) The high helium levels may be related to helium produced during radioactive decay of uranium in an enriched ore deposit or to a uraniferous phosphate deposit brought close to the surface by a shallow anticlinal or domal structure.

Because uranium, petroleum, and phosphate are all of economic importance and worthy of further investigation, it is recommended that a gridlike helium survey be conducted, followed perhaps by shallow coring, seismic surveying, and subsequent deep drilling.

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# INTRODUCTION

## Purpose

The purpose of this study was to evaluate the use of helium surveying in surficial soil gases as another means of prospecting for subsurface oil and gas deposits in south Florida. This was done to test the technique in an area characterized by seemingly unfavorable circumstances such as (1) deep burial of known crude oil deposits (about 11,500 ft), (2) low gas-oil ratio of Sunniland crudes (generally 100 to 1 or less), (3) the presence of the Floridan aquifer which could conceivably divert vertical migration of gases, and (4) the impermeable nature of many lithologic units in the Lower Cretaceous strata which could also impede upward movement of gases.

## Principle and justification of helium surveys

Briefly, the principle and justification for the use of helium surveys are that nearly all petroleum reservoirs contain helium ranging from 100 to 100,000 ppm by volume. Helium is generated from the radioactive decay of uranium and thorium minerals in sedimentary rocks in and around or below the reservoir or from deeper igneous and metamorphic basement rocks. The nearly ubiquitous association of helium with petroleum may simply be due to the fact that, as a gas, it migrates and accumulates in sedimentary traps in a manner similar to that of liquid or gaseous hydrocarbons. However, the entrapped helium, because of its small mass and atomic radius and its chemical inertness, has a greater chance to escape from a cap rock to the surface than do liquid or gaseous hydrocarbons. As helium ascends to the surface, it locally enriches the helium concentration above background (5,240 ppb) in soils or waters at or near the surface and causes an anomaly that can be measured and mapped.

One of the advantages of helium surveys is that a helium anomaly may reflect subsurface petroleum accumulations not only in structural traps but also in stratigraphic traps. However, care must be taken in the interpretation of helium anomalies, because they may be indicative not only of underlying petroleum accumulations but also of deposits containing radioactive elements, geothermal energy sources, and faults (Roberts and others, 1975; Dyck, 1976; Reimer and others, 1979).

In the South Florida basin, chances of finding economic geothermal sources are rated poor to nil owing in large part to the low geothermal gradient (Reel and Griffin, 1971) and absence of any recent volcanic activity. Deposits containing concentrations of radioactive elements as a source of the helium are not unreasonable, however, The phosphate deposits of Polk and Hillsborough Counties, Florida, some 100 m north to northwest of the area of investigation, contain generally 30-80 ppm uranium (Cathcart, 1978; Cathcart and McGreevy, 1959). Separated phosphate particles contain as much as 300 ppm. These deposits, of Late Tertiary age, particularly those in the Hawthorn Formation are probably present throughout all of South Florida (J. B. Cathcart, oral commun., 1979).

## Location

The helium survey was conducted in south Florida during February 4-8 1979. Because of a limited time frame, the swampy conditions encountered owing to heavy rains, and the difficulty in obtaining permission to survey on certain private lands, only three traverses were run and 76 measurements taken. The results, therefore, should be considered as only partially conclusive.

The plan was to make a quick survey over a known petroleum accumulation (the Sunniland oil field, Collier County), followed by a survey over an unexplored area that held some promise of possible subsurface oil accumulations.

The oil-prospective area, in north-central Collier County, east and northeast of the town of Immokalee, Florida (fig. 1), was selected on the basis of ongoing geologic and organic geochemical studies, some of the preliminary results of which have already been published (Palacas, 1978a, b).

## Factors responsible for selecting oil-prospective area

The key factor in the area selection is that free oil had been reported in the Humble Curry No. 1 well, in T. 47 S., R. 29 E., near to and structurally downdip from the area chosen for investigation. A 20-hour drill-stem test in this well at 9,850-9,863 ft in the Fredericksburg 'B' unit (approximately equivalent to the Dollar Bay Formation of Winston, 1971) recovered 15 ft of free oil and 25 ft of oil-cut mud. It was speculated that if commercial oil is present updip in this unit and if there is oil accumulation in the underlying Sunniland reservoirs (some 1700-1800 ft below the Fredericksburg 'B' unit), the chances of helium leaking to the surface and producing an anomaly would be enhanced.

A second factor is that in the vicinity of the Humble Curry No. 1 well and, indeed, in the area from the well east to the Humble Collier No. B-1 well, Hendry County and beyond, and probably throughout a large part of south Florida, the Fredericksburg 'B' unit contains abundant organic-rich, heavily oil-stained carbonate rocks that might have yielded commercially recoverable oil reserves (Palacas, 1978b, p. 371 and fig. 11.)

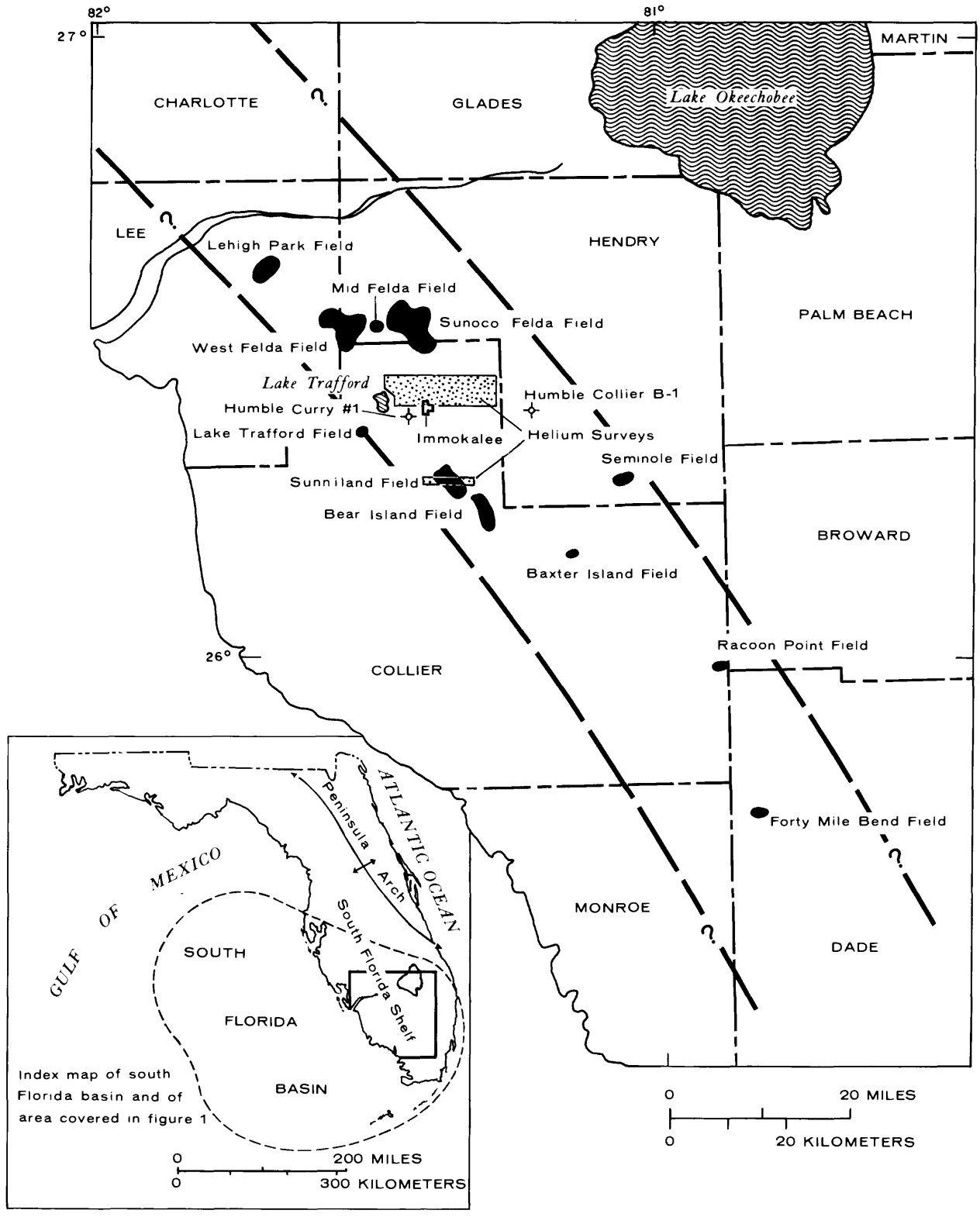


Figure 1.--Map showing areas of helium surveys, location of oil fields (black pattern), and present Sunniland producing trend (solid dashed lines). Accompanying index map shows outline of South Florida basin.

A third factor is the assumption that, because the area of investigation lies within the fairway of Sunniland oil production fig. 1, the chance of finding additional oil in the Sunniland is not unreasonable providing the necessary trapping and reservoir conditions are met. In support of a possible oil accumulation in this area, oil shows were reported in the Sunniland Limestone in some of the surrounding wells; namely, the Humble Curry No. 1, sec. 8, T. 47 S., R. 29 E; the McCulloch Collier No. 1, sec. 20, T. 46 S., R. 29 E.; the Tribal Collier No. 2, sec. 23, T. 46 S., R. 29 E.; and the Sohio Collier No. 3, sec. 11, T. 47 S., R. 29 E. The shows were mainly in the form of bleeding oil, oil stains, and dead oil reported from core analyses and one oil-cut water-cushion recovery from a drill-stem test.

## SAMPLE COLLECTION AND ANALYTICAL PROCEDURES

Soil-gas samples were obtained by pounding a hollow stainless steel probe 0.5 m into the soil. The probe is fitted with a silicone rubber septum at the top and has holes drilled through the sidewalls at the bottom. A 10 $cm^3$ hypodermic syringe fitted with a sidehole needle is used to withdraw at least 5 $cm^3$ of gas in order to purge the dead volume (about 0.3 $cm^3$ of the probe.) This sample is discarded. A second sample is withdrawn through the probe, the needle is capped, and the sample is stored in the syringe for subsequent analysis of helium content.

Analyses were performed on a field-portable mass spectrometer-type leak detector mounted in a truck and modified for use as an analytical instrument (Friedman and Denton, 1975; Roberts and others, 1975; Reimer, 1976; Reimer and Denton, 1978). This instrument has an analytical reproducibility of 10 ppb of helium in air. Each sample was analyzed in duplicate, with a complete analysis, including comparison to standard samples, taking an average of 3-4 minutes.

## RESULTS AND DISCUSSION

One east-west traverse consisting of 10 sample points was made in the Sunniland field. Helium contents in four of the samples within the field were 40-60 ppb above background (5,240 ppb); the other six samples, three on either side of the field, were 0-20 ppb above background. Although the results indicated a positive anomaly of low intensity, not enough sampling points were available to come to any definite conclusions. Obviously more samples on a grid pattern should be taken. It is also recommended that a similar survey be conducted over at least one or two additional fields.

In the prospective area, in the vicinity of the town of Immokalee, Florida, samples for analysis were obtained in two traverses (A-B-C-D-E and F-C-B-C-H-J-K (Fig. 2).The helium concentrations are plotted in parts per billion above background (5,240 ppb $\pm$ 20) (fig. 3). Traverse A-B-C-D-E revealed no pattern of significantly high helium values and is typical of a traverse run in areas of only background helium concentrations. Traverse F-G-B-C-H-J-K, on the other hand, revealed a region of abnormally high helium values, ranging from 40 to 140 ppb above background in an area just east of Immokalee.

We believe that such anomalously high concentrations of helium may be related to microseepage from a buried petroleum reservoir with subsequent migration to the earth's surface. Roberts and others (1975) and Roberts (unpublished data, 1979) have run similar helium surveys over eight known petroleum accumulations in a variety of geological and climatic environments extending from northern Alaska through the central portion of the United States and into Central America. In seven of the eight cases studied, definite analogous associations of high helium-in-soil-gas concentrations were correlated with the buried reservoirs.

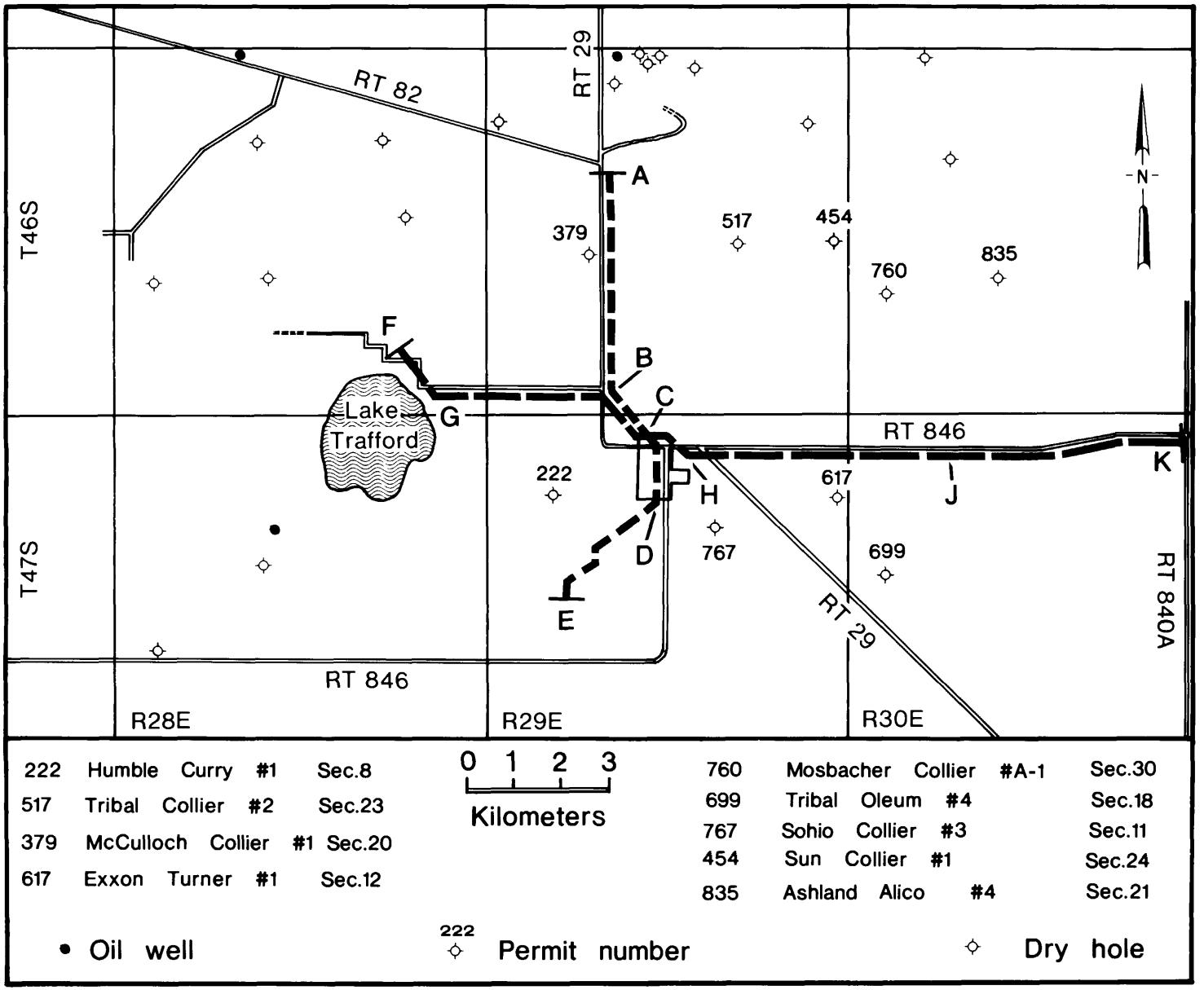


Figure 2.--Location of helium surveys along traverses A-B-C-D-E and F-G-B-C-H-J-K made in the oil-prospective area near Immokalee in north-central Collier County, Florida.

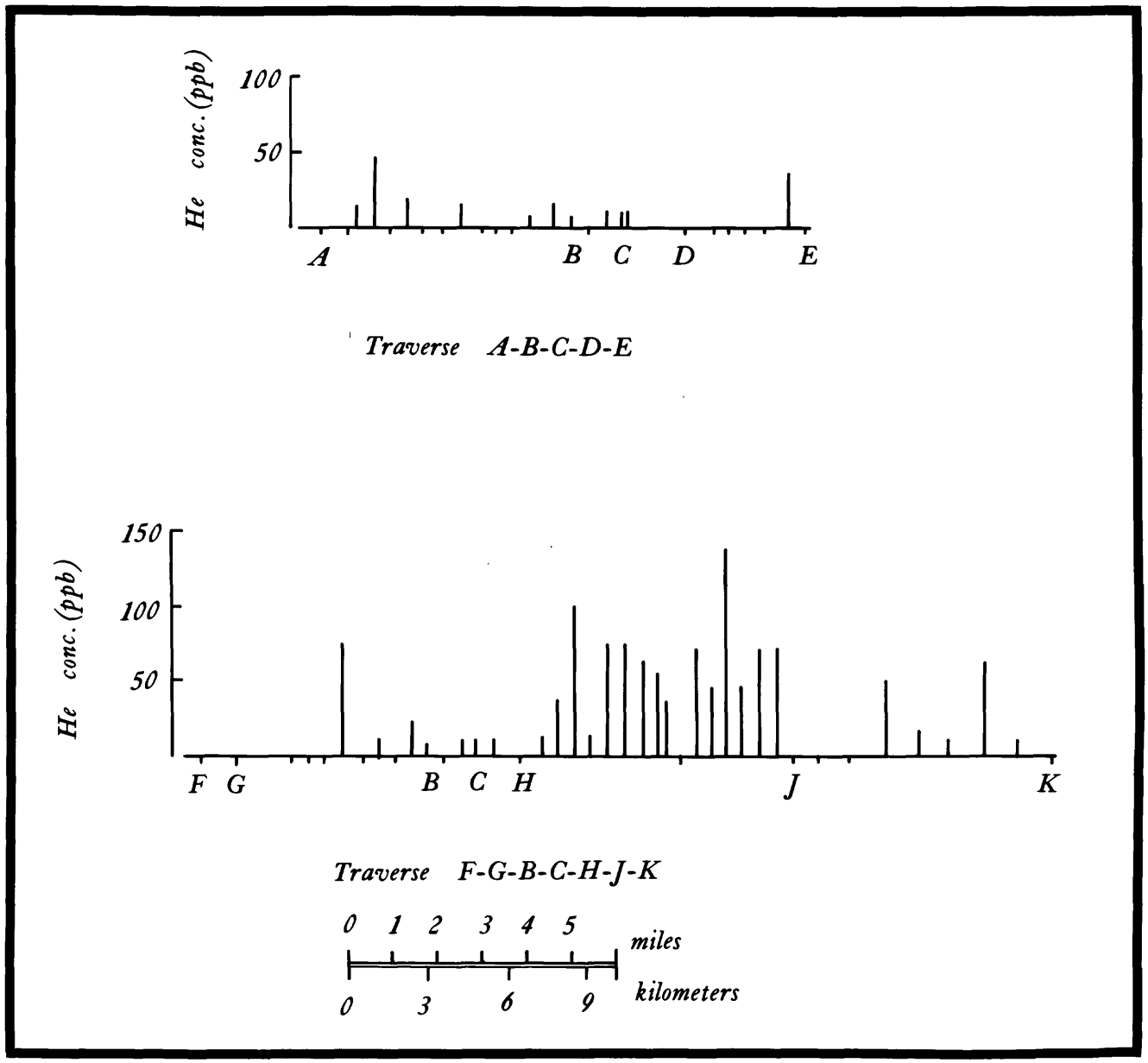


Figure 3.--Plots of helium concentrations in ppb above baseline along traverses A-B-C-D-E and F-G-B-C-H-J-K (fig. 2).

Another possible source of such high helium values may be related to leakage from shallow buried uranium-bearing minerals. Such anomalous helium values have also been observed to be associated with uranium deposits of other areas (Dyck, 1976; Reimer and others, 1979). In the study area, uranium, if present, is most likely associated with the underlying phosphate deposits of Late Tertiary age, particularly those in the Hawthorn Formation of Miocene age.

If, indeed, the helium anomaly is related to the shallow phosphate deposits, then two possible interpretations of subsurface conditions are offered. First, the high helium concentrations may reflect an enriched shallow-uranium deposit which, if large enough, may, in itself, be economic. Second, the helium anomaly may reflect leakage from a shallow anticlinal or domal structure which has brought the uranium-bearing phosphate deposits close to the surface.

If the latter interpretation is correct, then two important implications follow: (1) if the phosphate deposits are thick, rich, and close to the surface, they may be economically exploited by strip mining, and uranium may be recovered as a byproduct; and (2) the shallow anticlinal or domal structure may be reflecting a larger structure at greater depth. Assuming the latter to be true, then the chances of finding hydrocarbon accumulations in various stratigraphic horizons are enhanced.

Additional, more detailed helium surveying accompanied by shallow core drilling, would help to determine whether shallow structures or radioactive deposits are responsible for the surface helium anomaly.

## SUMMARY AND CONCLUSIONS

The helium surveying technique as a means of prospecting for oil and gas in south Florida was evaluated in two different areas. In the first, a single east-west traverse consisting of 10 sample points was run over the Sunniland field. A minor but positive helium anomaly was detected. Because of the limited number of samples taken, the results should be considered as only partially conclusive. Nevertheless, the results were encouraging enough to continue the helium surveying in an unexplored oil-prospective area.

Two traverses, one approximately north-south and the other east-west, consisting of a total of 66 sample points were run across the oil-prospective area in the vicinity of Immokalee, Florida. A significant helium anomaly with helium concentrations ranging from 40-140 ppb above background (5,240 ppb) was discovered in the area east of the town of Immokalee. Based on previous studies in other areas (Roberts, 1979), the helium anomaly strongly suggests leakage from a subsurface petroleum deposit.

On the other hand, the anomaly may be related solely to helium produced in the radioactive decay of uranium in an enriched deposit at shallow depth or to a uraniferous phosphate deposit that has been brought close to the surface by a shallow anticlinal or domal structure. Either type of deposit, of course, is a critical natural resource and of current economic importance, hence worthy of further investigation.

A more detailed study should be undertaken, but only drilling can adequately test the petroleum potential of Lower Cretaceous carbonates in the study area.

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