DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

A possible new source of natural gas in the eastern West Virginia panhandle

By

H.A. Pohn*, A.A. Roberts**, G.M. Reimer**, and R.L. Forgey**

Open File Report No. 84-556

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

*USGS Reston
**USGS Denver

1984

A possible new source of natural gas in the eastern West Virginia panhandle

By

H.A. Pohn, A.A. Roberts, G.M. Reimer, and R.L. Forgey

ABSTRACT

Using a combination of structural field mapping, examination of proprietary seismic data, and similarities of surface and subsurface structure to a nearby proven gas field, we have identified an area in the West Virginia panhandle, south of Berkeley Springs which may be a developable reservoir.

The existence of this possible reservoir was first suspected because of a surface concentration of disturbed zones (narrow bands of intensely deformed and thrust faulted rock). Disturbed zones are believed to be the surface manifestation of splay thrusts or ramps which rise from major decollements. Concentrations of these zones produce areas of fracture porosity which have the potential to serve as gas reservoirs.

A recently mapped concentration of disturbed zones is present near the Sleepy Creek anticline just southwest of the village of Berkeley Springs (Bath), West Virginia. The surface rocks (Chemung Formation), the type and concentrations of disturbed zones, and the subsurface folding and faulting seen on propreitary seismic data are remarkably similar to those features in the Augusta field in the east Whip Cove anticline, a producing field 55 kilometers to the southwest of the Sleepy Creek anticline.

Tests for anomalously high concentrations of helium in soil gas (commonly associated with subsurface features, including faults and hydrocarbon accumulations) were conducted in August, 1983. Analysis of the data reveals no helium anomaly over the most of the disturbed zones in the Sleepy Creek anticline area. Similarly no concentrations of helium were found in the soils directly over known production areas in the Augusta field.

Several areas not apparently related to disturbed zones do show helium concentrations significantly above background levels. The reason for these anomalies is not known at present.

We believe that a careful look should be taken at the Sleepy Creek anticline for possible accumulations of natural gas.

Introduction

For the past five years, the senior author has been mapping disturbed zones in the Valley and Ridge and Appalachian Plateau provinces of Pennsylvania (Pohn and Purdy, 1982), Maryland, West Virgina, Virginia. Disturbed zones are sequences of highly folded and thrust faulted beds, either the hanging wall of a thrust fault, or in a zone trapped between a pair of series of approximately parallel thrust faults. An overwhelming body of evidence has emerged from the mapping of nearly one thousand disturbed zones that these zones are surface manifestiations of splay faults or ramps which merge at depth into major decollements. Many disturbed zones can be followed along the surface as extensions of previously mapped faults, others occur in fault zones in which direct evidence shows considerable stratigraphic displacement. Still others occur as upward extensions of faults mapped in the subsurface from reflection seismic data and drill holes.

Furthermore Purdy and the first author have observed that concentrations of disturbed zones are coincident with gas fields and areas of intense interest to hydrocarbon exploration companies. Richard Beardsley of Columbia Gas Tranmission (Oral Communicationm, 1983) confirms this association.

The reason for the association of disturbed zones with hydrocarbon traps is apparent if one examines a schematic cross-section of such a concentration (fig. 1). the folding and extreme faulting in a formation such as the Oriskany Sandstone increases considerably the fracture porosity of the formation both within and around the disturbed zones. The same faults which fracture the Oriskany Sandstone are taken up by flowage and concomittent disharmonic folding in the superjacent shale beds (the Needmore and Marcellus shales) which serve to seal the reservoir. Thus, the gas becomes trapped in the intersticies and fractures within the sandstone.

In the past year, field mapping of disturbed zones showed that two concentrations of disturbed zones were present in the eastern West Virginia panhandle. One concentration was over the Whip Cove anticline (Fig. 2) and a second quite similar concentration was over the Sleepy Creek anticline, approximately 55 kilometers to the northeast. Examination of the geologic map of West Virginia (Cardwell and others, 1968) as well as field mapping showed that both concentrations occurred in the Chemung Formation. Recently the senior author had the opportunity to examine some proprietary seismic lines which crossed both of these anticlines and was able to determine that structures in the subsurface of both anticlines were remarkably similar.

With these similarities in mind, the authors decided to run a series of traverses across both anticlines using a technique which measures the concentration of helium gas within the soils. Anomalously high concentrations of helium are often associated with petroleum and natural gas reservoirs and with faults or fault systems.

Methods and Results

The helium surveys were conducted using techniques developed at the USGS for this purpose (Reimer, 1976 a and b; Roberts, 1981). Soil gas samples were collected at 3/4 meter depth along roadsides within the study area utilizing stainless steel probes. The helium content of these gases was determined within 5 hours of collection using a field-portable, mass spectrometer-type, helium analyzer developed by the USGS (Friedman and Denton, 1976; Roberts and others, 1975; Reimer, 1976b; Reimer and Denton, 1978). Precision of the analytical system is better than 20 ppb/V (parts per billion by volume). All samples are reported in terms of concentration above the atmospheric content of helium which is found to be remarkably constant at 5.24 ppm/V (Glueckauf,1946; Reimer and others, 1976).

A helium survey consisting of about 150 soil-gas samples was run in the vicinity of the Augusta gas field, around Augusta, West Virginia. Several traverses with samples taken at 1/3 km centers and one traverse with samples at 80 m centers were run. The sample locations and the locations of the high helium analyses for the samples taken at the greater spacing are shown in figure 3. Also shown are well locations and faulting in the Oriskany Sandstone presented by Jacobeen and Kanes (1974). Figure 4 displays the results of the helium analyses from the more tightly spaced traverse (A-A') along with the location of the faults from Figure 3.

The Oriskany Sandstone in this area is separated into at least three thrust slices, with hydrocarbons produced mainly from fracture porosity within the structurally highest thrust block (Jacobeen and Kanes,1974). The shales of the overlying Onondaga and Marcellus Formations form the reservoir seal. The eastern edge of the field is bounded by a westward-dipping thrust fault shown as the easternmost fault in Figure 3.

Examination of the values in Figure 3 reveals only a few samples with helium concentrations significantly above background. Values those more than 40 ppb/V above atmospheric concentrations are considered significant and are displayed as large circled dots in the figures. There is no apparent correlation between high values and the known producing area. There are several possible reasons for such a lack of an anomaly. The gas associated with the hydrocarbons may have an unusually low helium content and hence only insignificant amounts of helium would migrate to the near-surface. However, the USBM has published an analysis of a gas from the Oriskany Formation in the Sherman District containing the Augusta field reporting a helium content of 0.08% (800,000 ppb) (Moore, 1976). While this is not a high concentration for helium from natural gas, it should be enough to allow detection of microseepage of the natural gas with subsequent vertical migration of the gas to the near-surface soils. A second possibility is that the cap rocks are impermeable to gas migration allowing insignificant quantities of gas to escape directly through the rocks to the overlying the field. A third possibility is that gas is displaced horizontally as it migrates toward the surface through the action of moving ground water or through migration along dipping, highly permeable faults or fault systems.

An examination of Figure 4 shows that the dominant feature is a definite, non-random clustering of moderately high helium values along the eastern end of the traverse. These values are all in close proximity to the westward-dipping thrust fault through the Oriskany Formation to the east of production in the Augusta Field (Jacobeen and Kanes, 1974). Previous work has shown that soil-gas helium concentrations more than 40 ppb/V above atmospheric (hereafter referred to as high helium) rarely occur unless there is some subsurface source of excess helium or possibly a depletion of one of the other normal components of the soil-gas mixture. It is, however, possible that this grouping of high values is related to some other source of helium and is only coincidentally observed close to the mapped fault. Further, although somewhat tenuous, support of a causal relationship is found in examination of the analyses of the samples in the rest of the survey. Although the number of samples taken close to the projection of the fault is too few to allow definite conclusions to be drawn, 18% of the samples obtained within 300 m. of the fault are observed to be high whereas only 3% of those more distant are high in helium content. We feel that it is quite reasonable for this fault to be related to high helium values found in the soil. The fault is believed to intersect both the gas-bearing sands of the Oriskany formation and the overlying shales which act as the top seal (Jacobeen and Kanes, 1974). Thus, the fault could be acting as a conduit for seepage of some of the helium-bearing gases found in the reservoir through the cap rock which subsequently migrate vertically to the near-surface. However, further work involving the collection of many more samples along this proposed fault trace would be necessary for a good test of this hypothesis.

A helium survey was also run over much of the Stotler's Crossroads 1:24000 quadrangle in the eastern panhandle area of West Virginia. This survey involved the collection of more than 200 soil gas samples along roads at 400 m. spacing. On selected traverses, samples were collected at 200 m. spacing in an attempt to determine whether or not disturbed zones identified in outcrop are areas of abnormally high permeability to migrating gases and hence identifiable as areas of higher helium concentrations.

The sample locations are shown on the "contour" map in Figure 5. Due to logistical considerations the samples were not collected in a regular grid pattern and as such are not amenable to meaningful display using routine contouring procedures. Instead a "contouring" program (Reimer and Dean, 1979) was used which allows for a smoothing of the data by nearest neighbours (within ca. 1100 m.) weighted inversely by the square of the distance to the neighbouring samples.

Within the Stotler's Crossroads 7 1/2-minute quadrangle by far the most noticeable disturbed zones are observed in outcrops along the road that leads east-southeast out of the town of Berkeley Springs (marked A - A' in Figure 5). The helium concentrations in soil gas samples taken along this traverse are shown in Figure 6 along with the limits of the mapped disturbed zone. There is a subtle but distinct increase in the helium concentrations within the disturbed zone. This would support the hypothesis that this zone represents an area of increased permeability for the migration of gases from the subsurface. In the other areas within this quadrangle where disturbed zones have been identified no correlation is apparent between higher helium in soil gas and the mapped disturbed zones although extensions of disturbed zones to zones outside the map do pass through some high helium anomalies.

There are several other distinct areas within the survey that display significantly higher concentrations of helium than could reasonably be attributed to random fluctuations in the helium content of the soils. The first of these is the area directly south of Berkeley Springs in which six samples contained more than 50 ppb/V in excess of atmospheric concentrations. In our experience, such a grouping of anomalously high levels of helium must be related to some subsurface source. The linear nature of this anomaly suggests that it might be related to a permeable fault or fault system which facilities the escape and migration of minor amounts of gas from subsurface sources. This situation is directly analogous to that hypothesized for the Augusta area described above. Another possible source for such a linear helium anomaly is slightly leaky gas pipeline buried along the road south out of Berkeley Springs. We do not feel that this is the likely explanation of this anomaly for two reasons. Previous work in areas, where pipelines were buried that were observable through helium measurements, were characterized by a distinctly different pattern of high helium values. The helium readings associated with minor leaks from such pipelines tend to be much higher, with the extent of any given anomaly much more areally restricted, than is observed in this anomaly. In addition no physical evidence of a buried pipeline was observed along the road such as signs, markers, or a disruption of the vegetation typical of a relatively recently laid pipeline.

The other area of anomalously high helium concentrations roughly covers the southern third of the survey. Examination of Figure 5 shows that these fall into two somewhat distinct anomalies; one to the southwest and one to the southeast. Only four main natural sources of such helium anomalies are thought to exist: 1) faults or fault systems, 2) petroleum or natural gas reservoirs, 3) uranium, thorium, or related ore bodies, and 4) thermal waters. In the absence of more extensive knowledge of the subsurface geology in the area we can only speculate as to the probable cause of these anomalies. These anomalies are not characterized by the linear trend and narrow nature of helium anomalies found to be associated with permeable faults. However, they could be caused by zones of intense faulting and fracturing increasing the permeability to migration of gases from subsurface sources. Thus it is possible that they are related to disturbed zones that are not evident in outcrop in the region. Another possibility would be that the high helium concentrations are a result of microseepage of petroleum related compounds, such as helium, directly through the cap rock of a petroleum reservoir with subsequent migration to the near-surface (Ball and Snowdon, 1973; Roberts and others, 1975; Palacas and Roberts, 1980; Pogorski and Quint, 1981; Roberts, 1981). The shape of these anomalous areas is typical of anomalies from such helium sources. A third possible source of helium in this area would be subsurface thermal waters. Geothermal reservoirs and hot springs are often observed to contain high concentrations of dissolved helium that can result in increased concentrations of that gas in the soils overlying the thermal waters (Roberts, 1975; Roberts and others, 1975; Denton, 1976; Denton, 1977; Hinkle, 1980; Wescott, 1980; McCarthy and others, 1982). Many warm springs are found within this general area of West Virginia including the one in the town of Berkeley Springs (Bath) from which its name is derived. The pattern of these anomalies, however, is not typical of the patterns that we have observed associated with hot or warm springs in the Western United States. These patterns are more areally restricted zones of anomalous helium with the concentrations rising dramatically as the samples near the springs. This nature of the pattern is believed to be a direct result of the fact that the waters are relatively near-surface themselves and as such the helium has not had much of a chance to disperse horizontally prior to migrating into the soils. Uranium, thorium, and many of their daughter products produce helium during radioactive decay. The helium atom is nothing more than an alpha particle that has picked up two electrons to form a thermodynamically stable molecule. The shape, magnitude, and extent of the anomalies in the Stoler's Crossroads quadrangle are similar to those produced in soils related to uranium and related ores (Clark and Kugler, 1973; Dyck, 1976; Reimer and others, 1979). However, examination of the geology and geochemistry of this area suggests that near-surface uranium ores are not a likely occurrence and that these anomalies are not likely to be the result of proximity to such deposits.

Summary

We feel that the helium anomalies that we have observed within the Stotler's Crossroads quadrangle are likely to be related to petroleum or natural gas reservoirs in the subsurface or related to faults or fault systems that may allow communication between subsurface gases and the near-surface soils. Furthermore it appears as though the highest helium anomalies in both the Stotler's Crossroads quadrangle and the Augusta field are related to single permeable faults and that lower helium anomalies are related to less permeable concentrations of disturbed zones. Concentrations of disturbed zones should be of great interest to petroleum exploration geologists involved in this area. In addition, the concentrations of disturbed zones which show no helium anomalies should be carefully examined as a possible source of hydrocarbons.

REFERENCES

Ball, N. L. and Snowdon, L. R., 1973, A preliminary evaluation of the applicability of the helium survey technique to prospecting for petroleum: Geol. Survey of Canada, Paper 73-1B, pp. 199-202.

Clarke, W. B. and Kugler, G., 1973, Dissolved helium in groundwater: a possible method for uranium and thorium prospecting: Econ. Geol., v. 68, pp. 243-251.

Cardwell, D. H., Erwin, R. B., and Woodward, H. P., compilers, 1968, Geologic map of West Virginia: Morgantown, W. Va., West Virginia Geologic and Economic Survey, 1:250,000 scale.

Denton, E. H., 1976, Helium sniffer field test: Newcastle, Utah, 10-26 March 1976: U. S. Geol. Survey Open-file Rept. 76-421, 5 p.

_____, 1977, Helium sniffer field test: Roosevelt Hot Springs, Utah, October 1975 and March 1976, U. S. Geol. Survey Open-file Rept. 77-606, 6 p.

Dyck, W., 1976, The use of He in mineral exploration: J. Geochem. Explor., v. 5, pp. 3-20.

Friedman, Irving and Denton, E. H., 1975, A portable helium sniffer: U. S. Geol. Survey Open-file Rept. 75-532, 6 p.

Glueckauf, E., 1946, A micro-analysis of the helium and neon content of air: Royal Society of London, Proc., Ser. A, v. 185, pp. 98-119.

Hinkle, M. E., 1980, Survey of helium in soils and soil gases and mercury in soils at Roosevelt Hot Springs KGRA, Utah: U. S. Geol. Survey Open-file Rept. 80-613, 31 p.

Jacobeen, F. and Kanes, W. H., 1974, Structure of Broadtop synclinorium and its implications for Appalachian structural style: Amer. Assoc. of Petrol. Geol. Bull., v. 58, pp. 362-375.

McCarthy, K. P., Been, Josh, Reimer, G. M., Bowles, C. G. and Murrey, D. G., 1982, Helium and ground temperature surveys at Steamboat Springs, Colorado: Dept. of Energy Special Publication 21, 12 p.

Moore, B. J., 1976, Analysis of natural gases, 1917-74: U. S. Bureau of Mines Computer Printout 1-76, 734 p.

Palacas, J. G. and Roberts, A. A., 1980, Helium anomaly in surficial deposits of South Florida-- possible indicator of deep subsurface petroleum or shallow uranium-associated phosphate deposits: U. S. Geol. Survey Open-file Rept. 80-91, 14 p.

Pogorski, L. A. and Quirt, G. S., 1981, Helium emanometry in exploring for hydrocarbons: part I: Unconventional methods in exploration for petroleum and natural gas II, B. M. Gottlieb ed., SMU Press, Dallas, pp. 124-135.

Pohn, H. A. and Purdy, T. L., 1982, Disturbed zones: Indicators of deep-seated faulting in the Valley and Ridge and Appalachian structural front in Pennsylvania: U. S. Geological Survey Open-file Rept. 82-967, 42 p., 28 figures.

Reimer, G. M., 1976a, Helium detection as a guide for uranium exploration: U. S. Geol. Survey Open-file Rept. 76-240, 14 p.

______, 1976b, Design and assembly of a portable helium detector for evaluation as a uranium exploration instrument: U. S. Geol. Survey Open-file Rept. 76-398, 18 p.

Reimer, G. M. and Dean, V. C., 1979, Computer program for the Hewlett-Packard 9825A to contour and plot data collected from helium surveys: U. S. Geol. Survey Open-file Rept. 79-865, 15 p.

Reimer, G. M. and Denton, E. H., 1978, Improved inlet system for the U. S. Geological Survey helium sniffer: U. S. Geol. Survey Open-file Rept. 78-588, 4 p.

Reimer, G. M., Denton, E. H., Friedman, Irving and Otton, J. K., 1979, Recent developments in uranium exploration using the U. S. Geological Survey's mobile helium detector: J. Geochem. Explor., v. 11, pp. 1-12.

Reimer, G. M., Roberts, A. A. and Denton, E. H., 1976, Diurnal effects on the helium concentration in soil-gas and near-surface atmosphere: U. S. Geol. Survey Open-file Rept. 76-715, 6 p.

Roberts, A. A., 1975, Helium surveys over known geothermal resource areas in the Imperial Valley, Calif: U. S. Geol. Survey Open-file Rept. 75-427, 6 p.

______, 1981, Helium emanometry in exploring for hydrocarbons part II: Unconventional Methods in Exploration for Petroleum and Natural Gas II, B. M. Gottlieb ed., SMU Press, Dallas, pp. 136-149.

Roberts, A. A., Dalziel, Mary, Pogorski, L. A. and Quirt, S. G., 1976, A possible petroleum related helium anomaly in the soil gas, Boulder and Weld Counties, Colorado: U. S. Geol. Survey Open-file Rept. 76-544, 7 p.

Roberts, A. A., Friedman, Irving, Donovan, T. J. and Denton, E. H., 1975, Helium survey, a possible technique for locating geothermal reservoirs: Geophysical Research Letters, V. 2, pp. 209-210.

Westcott, E. M., 1980, Helium and mercury in the central Seward Peninsula rift system: in Glenwood Springs Technical Conference Proceedings, v. 1, Earth Science Laboratory, University of Utah Research Institute Report #ESL-59.

ILLUSTRATIONS

Figure 1. Schematic drawing of the relationship of concentrations of disturbed zones to areas of high fracture porosity in the Oriskany Sandstone and to reservoir seals in the Marcellus Formation.

Figure 2. Location of disturbed zones in the West Virginia panhandle. Note the similarity of concentrations along the Whip Cove anticlines and the Sleepy Creek anticline.

Figure 3. Helium survey over the Augusta Gas Field

• = Sample location

⊙ = High helium sample location (more than 40 ppb/V above atmospheric)

= Dry hole

= Gas well

D/U = Thrust fault through Oriskany Formation (projected to the surface)

A-A' = Traverse detailed in Figure 4.

Figure 4. Helium sample traverse (80 m. spacing) south of Augusta Field

• = Sample location

⊙ = High helium sample location (more than 40 ppb/V above atmospheric)

D/U = Thrust fault through Oriskany Sandstone (projected to the surface)

Figure 5. Smoothed contour map of Helium concentrations, Stotler's Crossroads quadrangle, West Virginia. All values in ppb/V above air. Disturbed zones account for less than 1% of the outcrops in the area.

● = Sample location

A-A' = Traverse detailed in Figure 6

Isopleth interval = 20 ppb/V

heavy dashed lines connect disturbed zones (including some immediately outside map area)

Figure 6. Fence diagram of Helium concentrations in a traverse across the major disturbed zone in Figure 5. All values in ppb/V above air.

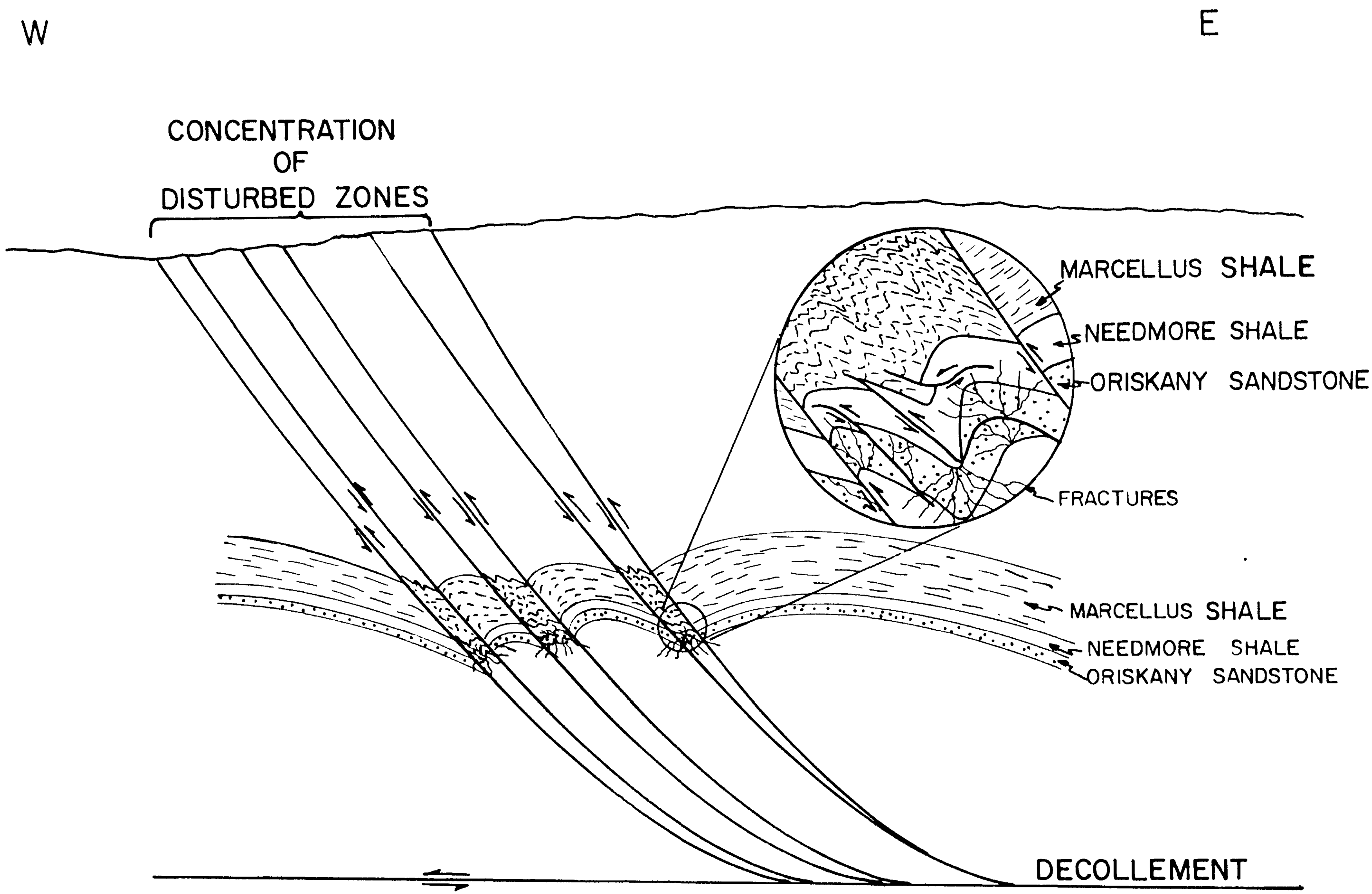
W
E
CONCENTRATION
OF
DISTURBED ZONES
MARCELLUS SHALE
NEEDMORE SHALE
ORISKANY SANDSTONE
FRACTURES
MARCELLUS SHALE
NEEDMORE SHALE
ORISKANY SANDSTONE
DECOLLEMENT

Fig 1

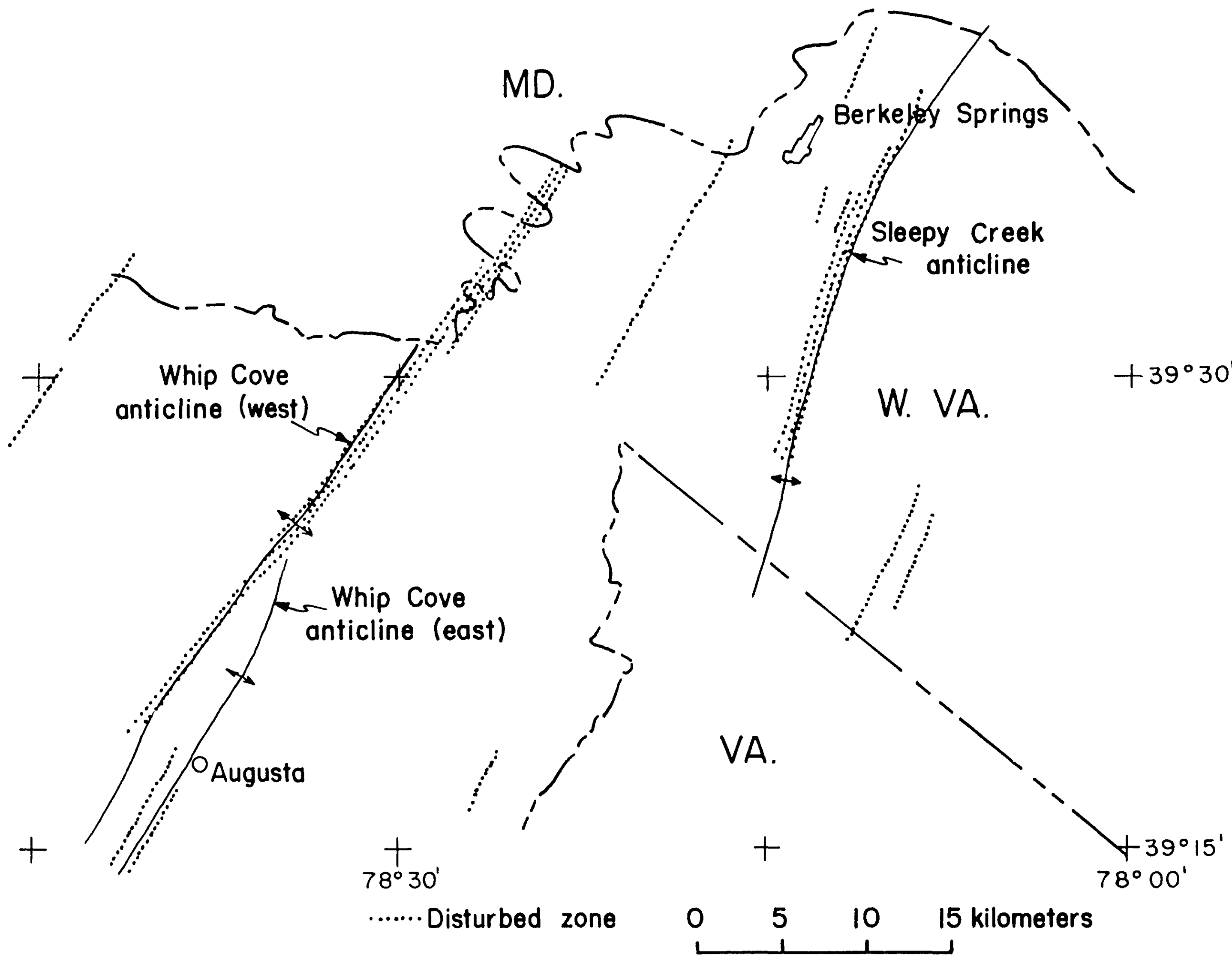
MD.
Berkeley Springs
Sleepy Creek
anticline
W. VA.
+39°30'
Whip Cove
anticline (west)
Whip Cove
anticline (east)
Augusta
VA.
78°30'
+39°15'
78°00'
Disturbed zone
0 5 10 15 kilometers

Fig 2

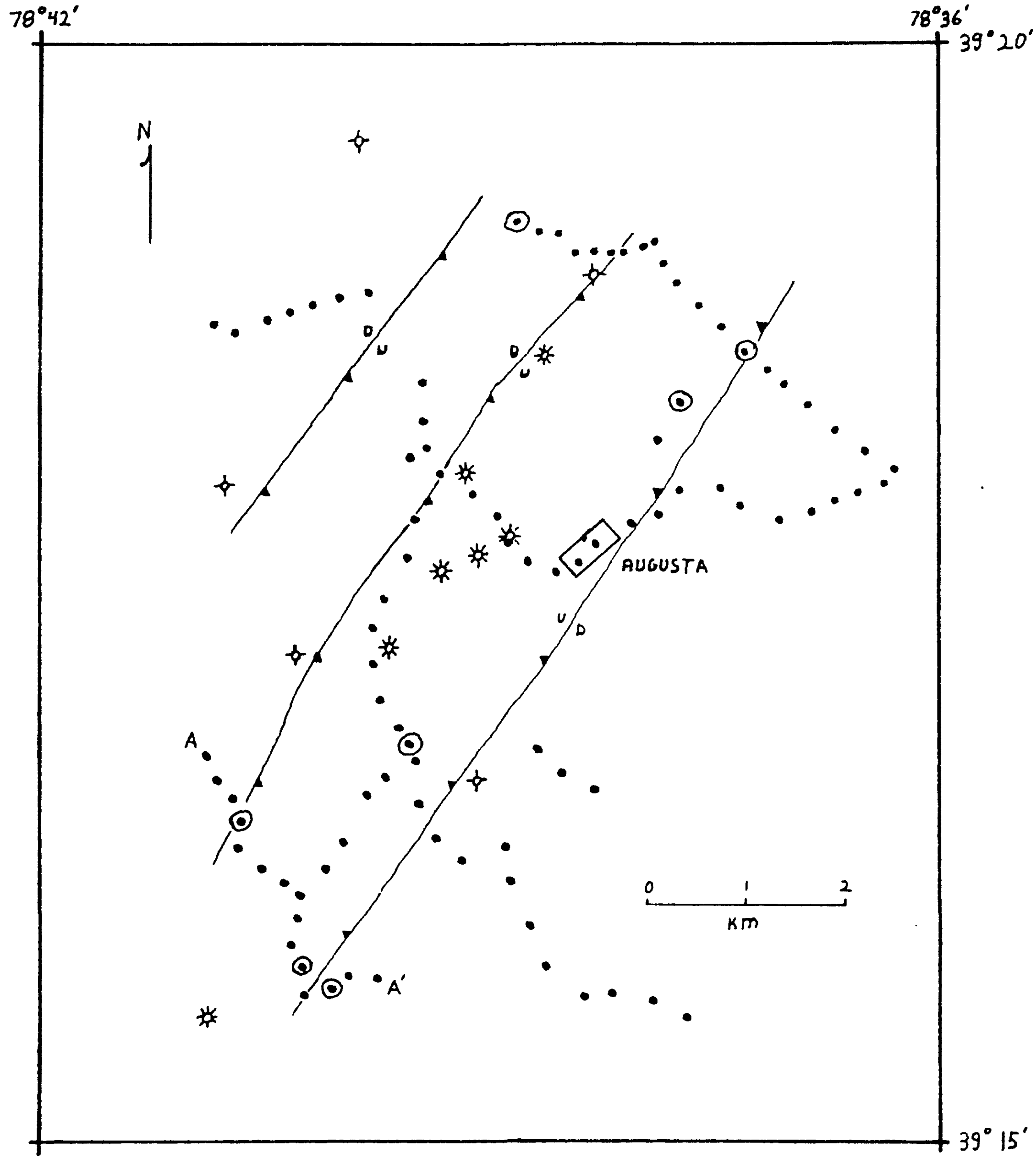

Fig 3

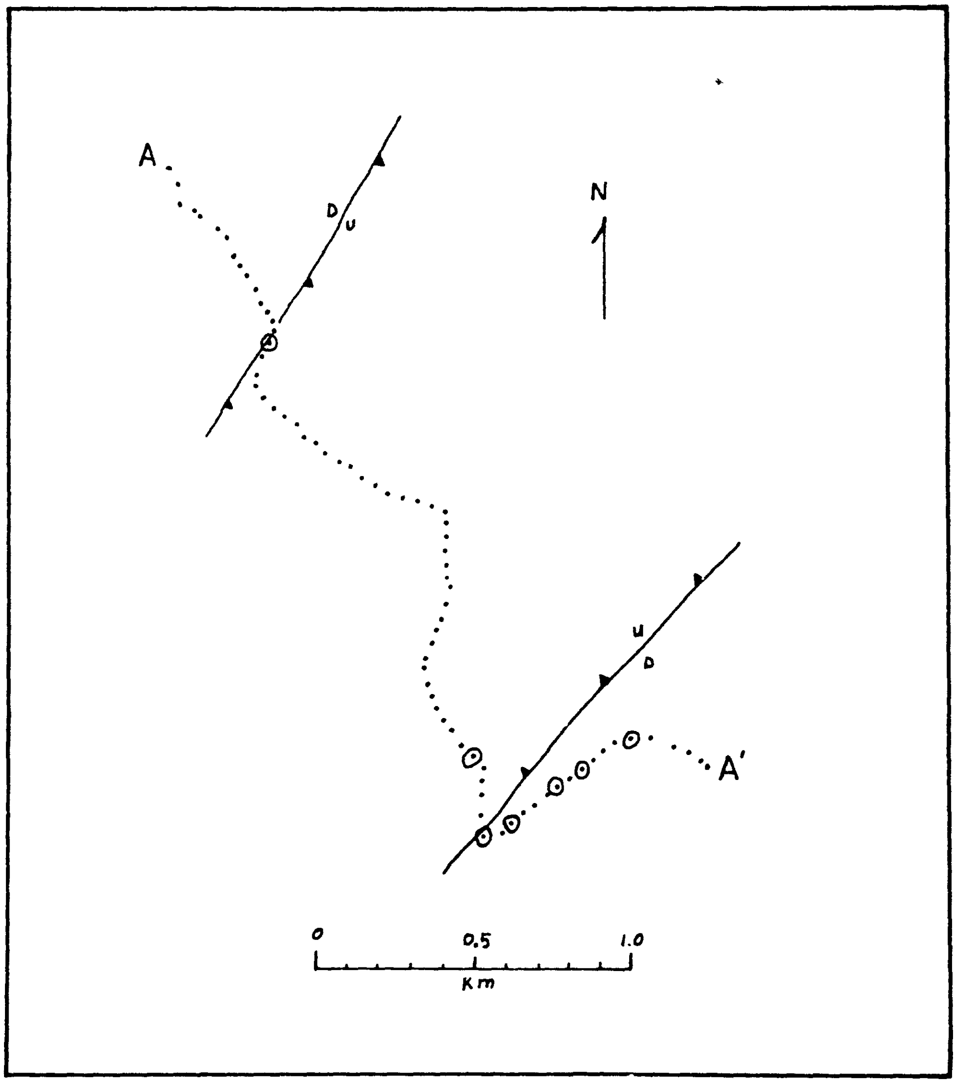

Fig 4

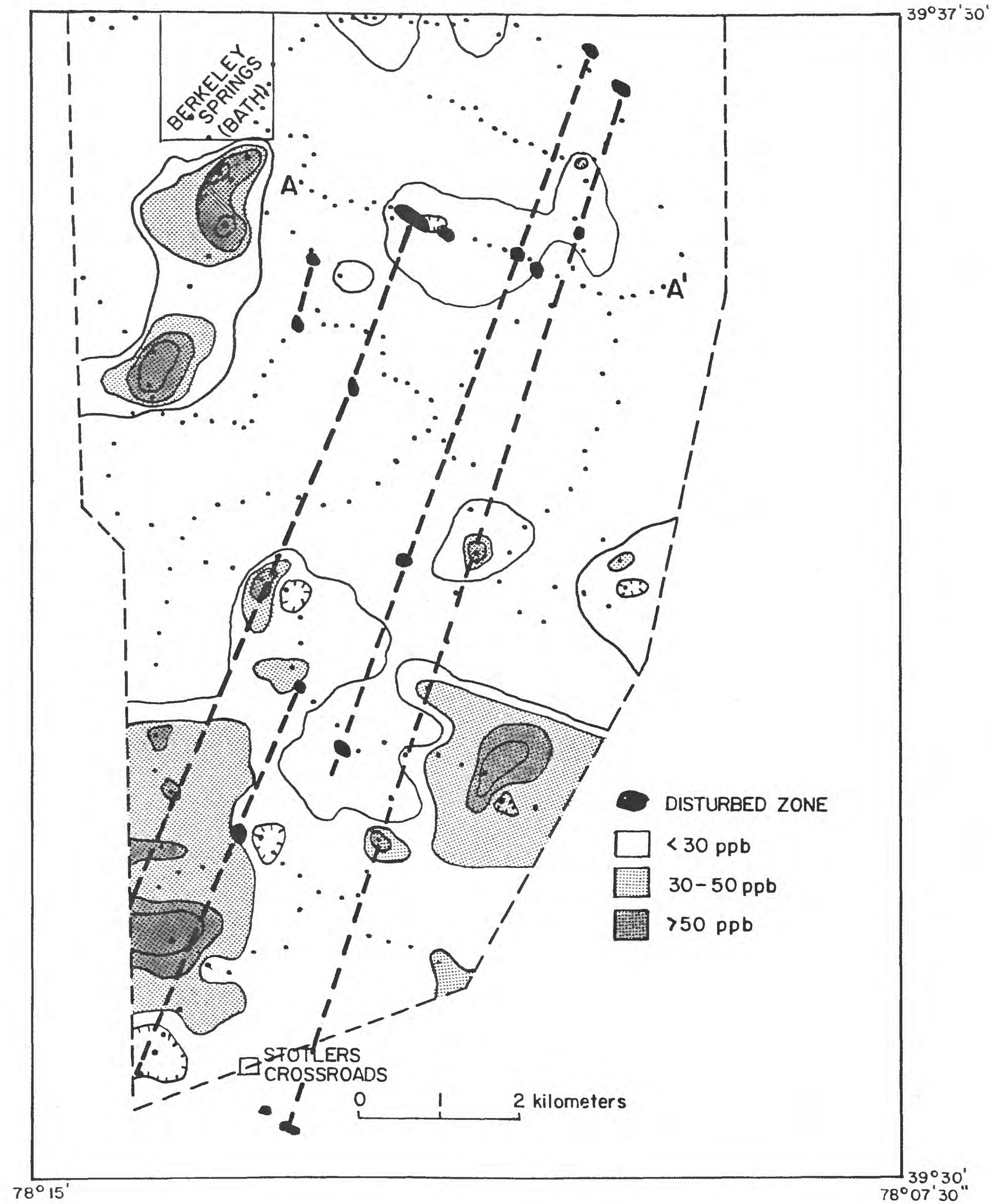
39°37'30"
BERKELEY SPRINGS (BATH)
A
A'
DISTURBED ZONE
< 30 ppb
30-50 ppb
>50 ppb
STOTLERS CROSSROADS
0
2 kilometers
39°30'
78°15'
78°07'30"

Fig 5

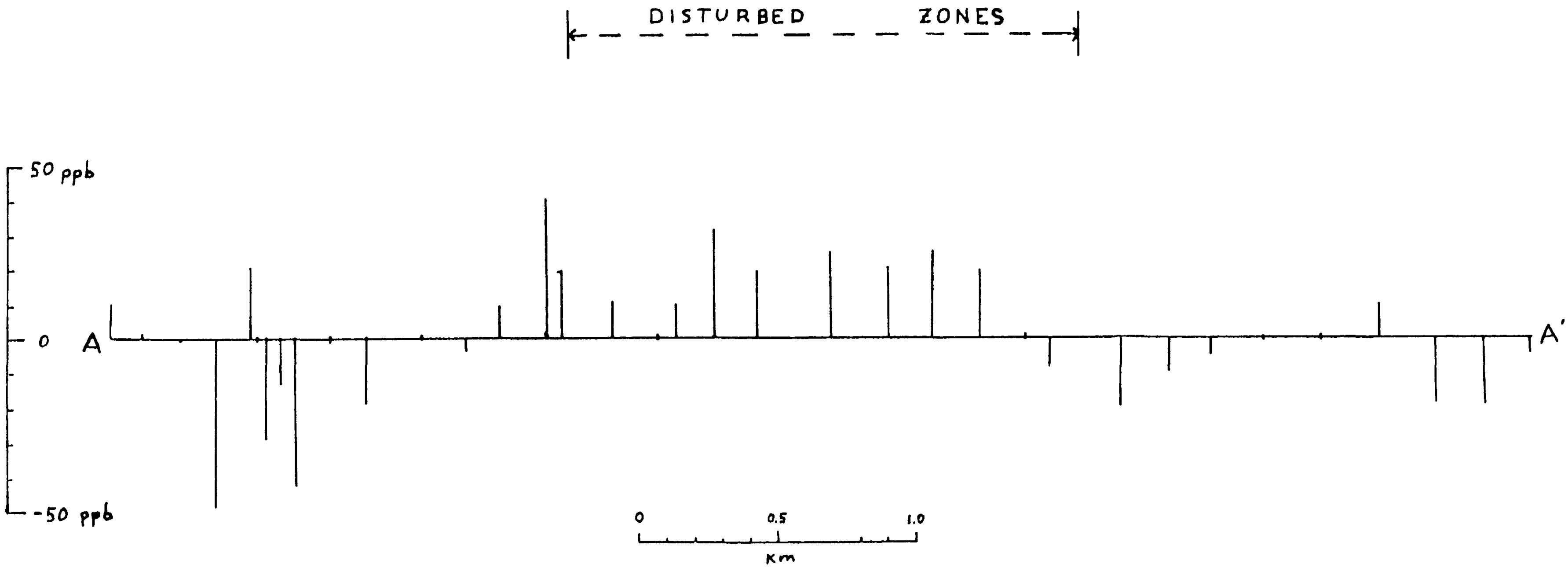

Fig 6