UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAR 4 1988

MEMORANDUM FOR: Thomas E. Murley, Director
Office of Nuclear Reactor Regulation

FROM: Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 151 "RESULTS OF MEERS FAULT INVESTIGATIONS"

The purpose of this memorandum is to transmit results of investigations into the nature of the Meers Fault in Oklahoma, a fault that has recently been recognized as showing signs of Recent* movement in terms of geological time. The investigations were performed by the Oklahoma Geological Survey and the U.S. Geological Survey cooperatively, and by the University of Nevada-Reno. Detailed results are described in the attached report on these studies.

Regulatory Issue: The immediate regulatory issue is to define the seismic hazard of the region in and around Oklahoma and to assess the potential impact of an active Meers Fault on the Wolf Creek and Comanche Peak nuclear plants. A wider issue is the intraplate seismicity of the Central and Eastern U.S. and the possible existence of active faults in this region. User need references for this subject are contained in the memoranda Jackson to Beratan, 13 January 1984; Denton to Minogue, 6 December 1984; and Brocoum to Beratan, 26 February 1985.

Conclusions Reached: The subject studies have resulted in the following main conclusions:

1. The Meers Fault is capable in terms of Appendix A to 10 CFR Part 100, and the last movement of the fault occurred about 1200 years ago.

2. The fault may have a recurrence interval of 10,000 years or more for significant earthquake-related movement.

3. No seismicity is presently associated with the fault.

4. The estimated maximum earthquake magnitude that could be generated by the fault is 6 3/4 to 7 1/2, based on statistical correlations between fault surface rupture length, maximum displacement, and earthquake magnitude.

Regulatory Implications: Results of these investigations mean that the Meers Fault itself is capable and that the possible existence of other active faults

*Recent (capitalized) or Holocene denotes the geological epoch extending over the last 10,000 years.

in the midcontinent region has to be considered. For example, at least one other fault has been found that shows indications of Recent movement. That fault, the Washita Valley Fault, is located on an extension of the Meers Fault trend, and both faults are part of a larger structural trend named the Amarillo-Wichita-Arbuckle Uplift. However, the search for active faults should not be limited to this particular structural trend.*

The fact that the Meers Fault is associated with a major structural trend confirms that tectonic activity that may cause earthquakes generally does not occur at random locations but is more likely to be associated with well-defined structural trends. This places renewed emphasis on a search for faults associated with major tectonic structures and on an effort to better define the structural fabric of the Central and Eastern U.S. The new results also support procedures specified in Appendix A to 10 CFR Part 100, namely the requirement that a capable fault be defined either by correlation of seismicity with tectonic structure or by geologic evidence for Late Quaternary movement. The Meers Fault investigations have shown that, although the Meers Fault is presently aseismic, there is geologic evidence for Recent seismogenic movement.

Restrictions on Applying These Results: The research summarized here is part of a continuing investigation of intraplate seismicity in the Central and Eastern U.S. The subject is complex and requires analysis of the simultaneous effects of many variables; it is not an engineering study with tests in a laboratory, where it is possible to isolate desired variables and study their effects individually. However, these and other recent studies, such as the New Madrid investigations and analyses of seismic network data, have brought new insights into the difficult problem of intraplate seismicity. The new results will have to be evaluated in detail to arrive at appropriate regulatory conclusions. Because of the complexity of the subject, such conclusions may not be applicable to all cases but will have to be considered in the context of an individual seismotectonic problem.

Unresolved Questions: A number of questions remain and are to be resolved by future studies. They are listed here and also under the conclusions of the attached report.

(a) The age of the last movement of the Meers Fault has been determined satisfactorily. However, confirmation of this age and improved accuracy by additional age dating are needed.

(b) The recurrence interval, for which only a rough estimate has been obtained, should be better defined.

*RES has an active program to further investigate the Meers Fault and other faults in the area. If signs of Recent activity are found on other faults, the program will be expanded to include other areas with structural configurations similar to the Meers Fault.

(c) The nature of the fault movement should be clarified. This includes evaluating the extent of lateral movement and the relationship between surface movement and movement at depth.

(d) The possibility of other faults being active in the Amarillo-Wichita-Arbuckle Uplift trend, including the Washita Valley Fault, should be further investigated.

(e) The question of whether there are other capable faults in the Cent and Eastern U.S. should be seriously pursued.

(f) The more general questions must be resolved as to what the relationships are between faulting and seismicity, and between active faults and the types of regional tectonic structures with which they are associated in the Central and Eastern U.S.

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Attachment: Detailed Report

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/S/

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Office of Nuclear Regulatory Research

Attachment: Detailed Report

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RIL # 151
— NRC PDR
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*See previous

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RESULTS OF MEERS FAULT INVESTIGATIONS

INTRODUCTION

1. Background

The Meers Fault, located in Southwestern Oklahoma, is part of a major NW trending fault system that separates the Wichita Mountains from the Anadarko Basin, which is the deepest sedimentary basin in North America. Part of this basin underwent a rifting phase in middle Cambrian time (530 million years ago) and is also referred to as the Southern Oklahoma Aulacogen. The Meers Fault, although one of the minor faults in this system according to surface length, had been known for a long time and was mapped in detail by Harlton (1951, 1963 and 1972). The fault offsets Permian beds (250 to 290 million years ago), and it had been assumed that it was a Permian structure and inactive until Gilbert (1983) observed features on the fault that seemed to indicate Recent movement (within the past 10,000 years).

Based on that discovery, the NRC contracted for two independent investigations of the Meers Fault. These investigations were performed by the Oklahoma Geological Survey and the U.S. Geological Survey (USGS) cooperatively, and by the University of Nevada-Reno. Details of these investigations are described in Luza et al. (1987) and in Ramelli et al. (1987).

The mid-continent in which the Meers Fault is located is a region of low to moderate seismicity, and historical and recent instrumental seismicity data show no association of epicenters with the fault. The neotectonics of this region and its relationship with seismicity are relatively poorly known. The type of seismicity present is classified as intraplate seismicity and has the following characteristics:

- Earthquakes occur within the continental crust.
- Recurrence rates are low.
- Few large earthquakes have occurred in recent history.
- Epicenters show only diffuse trends; no earthquake in the Central and Eastern U.S. has been conclusively associated with a surface fault.

Because of these characteristics and the relatively short interval of historical seismicity observations, it is particularly difficult to reach conclusions about the distribution of seismicity in space and time in this region. However, the discovery of probable Recent movement on the Meers Fault has revealed that certain recognizable tectonic features in the region may have earthquake potential associated with them.

2. Program of Investigation

Two separate research programs were established in 1984 in order to gain information on the Meers Fault that would permit resolving the questions of whether there has been Recent movement on the fault, what type of movement the fault has experienced, what age can be assigned to the movement, and what seismic potential may be associated with the fault. The first program, contracted to the Oklahoma Geological Survey with subcontract work by the USGS, had the purpose of conducting a geologic investigation of the fault in order to establish the configuration of the Meers Fault and the formations involved in the surface expression of the fault, to define the type and sense of movement, and to date the most recent movement on the fault. The second program of investigation, conducted by the University of Nevada-Reno, relied on low sun angle aerial photography and on surface morphologic studies to determine the type, sense and recency of movement, the length of visible faulting, and the seismic potential of the fault. These two lines of investigation were expected to complement each other and to produce different types of information that might give greater certainty to conclusions reached about the fault.

RESEARCH FINDINGS

1. Oklahoma Geological Survey/U.S. Geological Survey

(a) General Configuration of the Fault:

The Meers Fault is exposed at the surface as a scarp over a length of at least 26 km (Figure 1). The fault is characterized by a relatively straight trace and by a sharpness of the fault scarp that is evident in aerial photographs (Figure 2). Over most of its length, the fault offsets Post Oak Conglomerate and Hennessey Shale, two contemporaneous Permian formations. Previously, the fault had been assumed to be Permian in age (250 to 290 million years old). However, more recently it was found that Quaternary alluvial deposits (less than 1.6 million years old) are also offset by the fault.

The Meers Fault is part of the NW trending fault system that separates the Wichita Mountains from the Anadarko Basin. This fault system is dominated by moderately to steeply dipping reverse faults that have a combined vertical displacement of over 9 km which has occurred 290 million years ago or later (Permian). Of these faults, the Meers Fault has the greatest vertical displacement, about 6.4 km, which has occurred in the same time frame. There are also indications that large lateral offsets may have occurred on this fault system in Paleozoic times (250 to 570 million years ago). While the large Permian vertical displacements are down to the north, the present Meers Fault which trends N60°W exhibits a vertical surface offset of 3 to 5 m that is down to the south.

Neither historical seismicity nor two years of microearthquake monitoring by a seismographic station 2 km north of the fault have produced definite evidence of recent seismicity on the fault. Two possible earthquakes recorded by the microearthquake station may be quarry blasts. It is likely that no earthquakes of magnitudes greater than 4 have occurred on the Meers Fault since Fort Sill was established 116 years ago. Since the establishment of a seismic station at Tulsa, Oklahoma, 25 years ago, no earthquake exceeding magnitude 3 has been recorded from this area. Thus, the fault has been essentially aseismic for that period.

(b) Quaternary Stratigraphy:

In the southeastern portion of the study area, the Meers Fault crosses valleys whose alluvial stratigraphy can be used to date the fault movement. In this area, six fluvial allostratigraphic units were identified, ranging in age from Late Holocene (less than 2,000 years ago) to Middle or Early Pleistocene (1 million or more years ago). Five of the wider ranging units are shown in Figure 3. A sixth fan alluvium unit exists only in close proximity to the fault. Several of the youngest deposits were dated by radiocarbon age determinations, and results are shown in Table 1.

It was found that the f[illegible] crosscuts all but the youngest alluvial unit, the East Cache Alluvium whi[illegible] [illegible]ges in age approximately from 100 to 800 years. Stratigraphic relations [illegible] [illegible]dicate that movement occurred after 1280 ± 140 years ago but before 60[illegible] [illegible] years ago (Figure 4). It is assumed that faulting occurred nearer the [illegible]der limit than the younger one because of higher ages obtained from fan alluvium deposits, which were probably deposited soon after the streams were displaced by faulting.

(c) Trenching:

Two trenches were excavated across the fault near [illegible] Creek to study near-surface deformation and to obtain additional radiocarbon ages from selected samples. Trench 1 was excavated in Holocene alluvial deposits, whereas Trench 2 was excavated in Pleistocene terrace deposits.

Trench 1 shows Browns Creek Alluvium overlying Hennessey Shale (Figure 5). The faulting exposed is essentially a reverse fault with a block of alluvium that collapsed into a crack. The fault displacement of about 2.8 m is largely a product of flexing and warping in the area exposed by the trench. Only minor brittle deformation was found, amounting to about 10% of the total deformation. Organic materials yielded radiocarbon ages of 1660 ± 50 years ago to 1730 ± 50 years ago. These soil humus ages must be viewed as maximum ages for the fault movement.

Trench 2 was excavated in gravelly material of the Pleistocene Porter Hill Alluvium which overlies Hennessey Shale (Figure 6). The fault exposed here has a reverse sense of slip and a throw of about 0.6 to 1.0 m. However, the total stratigraphic throw is at least 3.2 m. so that, again, a larger portion of the total movement is due to warping. A radiocarbon date from the buried A horizon soil indicates an age of 1360 ± 50 years ago, which may be considered a minimum age for the fault movement.

Both trenches give indications of vertical fault movement. However, lateral movement cannot be proven or disproven from the available trench data. It is, therefore, possible that there is strike-slip movement in addition to vertical fault offset.

2. University of Nevada-Reno

(a) Regional Structural Configuration:

The Meers Fault is part of the larger Frontal Wichita Fault System. Detailed structural mapping in the Slick Hills and Wichita Mountains has revealed that significant left-lateral strike-slip occurred on this fault system and that the Meers Fault is the major strike-slip fault associated with this lateral movement. Interpretation of seismic profiles from the Consortium for Continental Reflection Profiling (COCORP, Brewer et al., 1983) has led to some conflicting views on the Meers Fault configuration at depth. The COCORP data seemed to suggest that the Meers Fault is a moderately south-dipping thrust fault. This is in conflict with other evidence, including the fault's linearity, that suggests that the fault is subvertical and dipping steeply to the north at the surface.

The Frontal Wichita Fault System itself is part of a larger structural alignment that can be termed the Amarillo-Wichita-Arbuckle Uplift. Recently it has been found (Cox and VanArsdale, 1986) that the Washita Valley Fault in the Arbuckle Mountains may also have experienced Recent movement and that it exhibits characteristics similar to the Meers Fault. The Potter County Fault in the Texas Panhandle was photographed and observed from the air, although no vertical aerial photographs were obtained. The fault shows probable surface rupture and left-lateral offset. Surface formations present in that area make it likely that the rupture is related to Quarternary movement. Surface geologic study is needed to confirm these observations on the Potter County Fault, and, in a wider sense, the fault system related to the Amarillo-Wichita-Arbuckle Uplift deserves further investigation to determine the extent of active faulting.

(b) Quarternary Fault Displacement

Low sun angle aerial photography led to the discovery of a previously unrecognized extension of the Meers Fault at its eastern end on the Fort Sill Military Reservation. This discovery, partially confirmed by field work, has extended the known length of the fault surface rupture to at least 37 km.

In comparison to other faults in the area with possible indications of recent fault displacement, the Meers Fault shows the clearest and most extensive expressions of such movement. It will be the subject of future research to decide whether the absence of extensive indications of recent tectonic activity other than on the Meers Fault is due to lack of preservation of surface features or to lack of activity.

Surface offsets on the fault were studied in detail. The offset is consistently up on the north side. The trenches excavated by the Oklahoma Geological Survey have shown that the fault dips northward near the surface and that the fault has moved in a reverse sense. This correlates with an evaluation of stress conditions and fault orientation which seem to preclude normal faulting.

Measurements of fault offset have yielded maximum offsets in the range of 5 m near the central portion of the fault (Figure 7). Offsets decrease towards the ends of the exposed fault. Horizontal offsets were also found, based on ridge lines and streamlines. These left-lateral offsets are 3 to 5 times as large as the vertical offset in a given location. Good indications of lateral offset are present only in the western portion of the fault where it cuts Post Oak Conglomerate. The Hennessey Shale seems to be too easily eroded to retain good lateral offset indicators for very long.

Scarp morphology (Ramelli et al., 1987; Luza et al., 1987) shows that the observed faulting has probably occurred within the last few thousand years. The preservation of fault morphology in two such contrasting formations as the Post Oak Conglomerate and Hennessey Shale also gives an indication of recency of movement (Donovan et al., 1983). Analysis of the trenches dug by the Oklahoma Geological Survey suggests that stratigraphic units with ages from 1,500 to 12,000 years (Madole, 1986) may not have been faulted by any previous events. This, in turn, suggests that the fault may have a recurrence interval of 10,000 years or more.

(c) Mechanisms and Magnitudes:

Southwestern Oklahoma follows the relatively uniform stress pattern of most of the Central and Eastern U.S., which is characterized by a maximum horizontal compressive stress oriented ENE-WSW to NE-SW (Zoback et al., 1986). The stress orientation and the WNW trend of the fault combine to permit left lateral or reverse displacement on the Meers Fault, depending on whether the minimum stress is oriented horizontally or vertically.

An estimate of the maximum magnitude of seismic events that may be generated by a rupture on the Meers Fault is needed to define the seismic hazard posed by this fault or by similar faults in the region. The intraplate seismicity of the Eastern U.S. may be associated with larger stress drops than the earthquakes common to the Western U.S. In addition, lower attenuation leads to much more widespread areas of damage for a given magnitude in the Eastern U.S.

By relating surface rupture length or maximum displacement to historically observed magnitudes, relationships between these parameters can be established and used to estimate magnitude expected for a fault with the characteristics of the Meers Fault. Although the data base for these regressions is not large enough to suitably take into account different types of faults, a magnitude of 6-3/4 and 7-1/2 can be estimated from fault length and maximum displacement, respectively.

Newer studies suggest that, for the Eastern U.S., this may be a low estimate (Scholz et al., 1986). According to Kanamori and Allen (1985) a fault with a long recurrence interval, such as the Meers Fault, may have higher stress accumulation and resulting stress drop, whereby a magnitude of 7-1/2 or greater could be expected from a fault of the length of the Meers Fault (37 km) and with a recurrence interval of 2,000 years.

SUMMARY AND CONCLUSIONS

1. Results

The Meers Fault was recently recognized as showing signs of Recent movement. Because the discovery of this type of fault in the mid-continent region is important for seismic hazard considerations, the NRC sponsored two studies to investigate the fault. In its general configuration, the fault trends N60°W and offsets not only Permian formations (250 million years ago) but also Quarternary formations (less than 1.6 million years ago). The fault is not isolated but is part of the fault system that separates the Wichita Mountains from the Anadarko Basin. This fault system is itself part of a larger trend which may be called the Amarillo-Wichita-Arbuckle Uplift and extends from the Texas Panhandle to Arkansas. The most important results obtained from the NRC-sponsored studies can be listed as follows:

(a) The fault is capable according to Appendix A to 10 CFR Part 100, the most recent movement having probably occurred between 1,400 and 1,100 years ago.

(b) Previous movement was apparently over 10,000 years ago suggesting a recurrence interval on the order of 10,000 years, or greater.

(c) Near-surface offset indicates reverse movement with an average vertical offset of 3 m and maximum offset of 5 m, up to the north. The total exposed length of the fault is 37 km.

(d) Left-lateral offset 3 to 5 times as large as the vertical offset is suggested by surface morphologic considerations. Lateral offset was not detected in the trenches dug under NRC sponsorship. However, newer trenches and unpublished results by the USGS have also produced evidence for lateral movement.

(e) Estimates of maximum earthquake size, based on surface rupture length and maximum displacement and taking intraplate conditions into account, suggest that an earthquake of magnitude 6-3/4 to 7-1/2 could be generated by this fault.

(f) Neither historic observations nor recent microearthquake monitoring have found any seismicity associated with the fault.

2. Discussion

The most outstanding fact to result from these investigations is that the Meers Fault has indeed experienced movement at least once during the last 35,000 years and is therefore capable according to the definition given in Appendix A to 10 CFR Part 100. This conclusion is based on two separate lines of reasoning, namely offset of stratigraphic units that are dated by C^{14} methods and morphology of the fault scarp. The age of that movement has been estimated to be a few thousand years at the most and, in fact, C^{14} dates indicate a probable age of about 1,200 years, thus making it a very recent movement on a geological time scale. The Meers Fault is apparently without any seismic expression in spite of the recency of movement on the fault. However, this type of behavior has been recognized in many cases, for instance in the Western U.S., where certain faults exhibiting recent surface rupture were quiescent until the moment when they generated a sizeable earthquake.

The new information about the Meers Fault has far-reaching implications with respect to the seismicity and seismic hazards in the Central and Eastern U.S.

In particular, it has given renewed emphasis to the search for Quaternary tectonic activity in this region. This is reinforced by the fact that, after the Meers Fault discovery, other faults in the region have been found that may have experienced movement in recent geological times. Among these are the Washita Valley Fault which is located on an en echelon extension of the Meers Fault trend, and possibly the Kentucky River Fault Zone which may have post-Pleistocene displacement (VanArsdale and Sergeant, 1987). A preliminary investigation of the Washita Valley Fault has produced evidence, such as a subdued surface expression and ponding of alluvium against the fault, which may indicate Recent movement and is similar to conditions on the Meers Fault. Other observed features, including up-to-the-north displacement, a N60°W strike, and steep to moderate north dip, are also reminiscent of the Meers Fault. The Kentucky River Fault System forms the northern boundary of the Rome Trough, which is a Paleozoic aulacogen. Evidence gathered suggests that the fault system has been active within the past five million years and probably within the last one million years. This movement is therefore relatively young geologically, but not young enough to make the fault system capable.

The new information on the Meers Fault also strengthens a concept that is contained in Appendix A to 10 CFR Part 100, namely that tectonic activity and associated seismicity do not occur randomly but can be correlated with tectonic structures. The Meers Fault, which is now known to be capable, is itself a tectonic structure, and it is associated with the Southern Oklahoma Aulacogen and the Amarillo-Wichita-Arbuckle Uplift. In the region east of the Rocky Mountains, the structures most suspect of being seismogenic may be those associated with the formation of Eocambrian rifts or Triassic grabens which may have created zones of weakness in the crust. Examples of such structures are the New Madrid Rift Zone and the Southern Oklahoma Aulacogen, of which the Meers Fault is a part. These two examples also exhibit certain divergent characteristics that may be present in such zones. The New Madrid zone has experienced large historical earthquakes and is still associated with considerable seismicity of low to moderate magnitude, whereas the Meers Fault has no known seismic expression in spite of the recency of its movement.

Seismicity in the Eastern and Central U.S. has been seen in the past as more or less diffuse with unclear or unknown correlation with causative tectonic structures. In recent years, studies performed to search for causes of earthquakes in this region and continued earthquake monitoring have provided an increasing body of evidence that shows that seismicity in many cases follows more definite trends than had been assumed. Some of the seismicity can be correlated with subsurface faults or other structures. Capable or potentially capable faults that have been found are not located in completely obscure areas but on major tectonic structures.

These new findings open up interesting possibilities for future research and point to the necessity to further investigate relationships between seismicity, tectonic structure, and capable faults in the Eastern U.S. and other intraplate regions. Recent advances in defining the stress field and its relationships to seismicity and potentially seismogenic structures may make it feasible in the future to use information on crustal stress and strain together with stress modeling as an acceptable method for defining structures with earthquake potential. At present it appears that, in a regulatory sense, certain types of structures are more suspect than others of being seismically capable. However, without evidence of Quaternary movement or associated seismicity they have to remain in the category of non-capable structures.

3. Recommendations

It has been established that the Meers Fault is a capable fault according to Appendix A. This is the first fault in the Central and Eastern U.S. known to be capable, and this fact should be incorporated into NRR's decisionmaking process. In addition, a number of questions remain that are to be resolved by future studies. They can be listed as follows:

(a) The exact age of the last fault movement should be confirmed and tied down more accurately by additional age dating.

(b) The recurrence interval, for which a rough estimate has been obtained, should be better defined.

(c) The nature of the fault movement should be clarified. This includes evaluating the extent of lateral movement and the relationship between surface movement and movement at depth.

(d) The possibility of other faults being active in the Amarillo-Wichita-Arbuckle Uplift trend, including the Washita Valley Fault, should be further investigated.

(e) The question of whether there are other capable faults in the Central and Eastern U.S. should be seriously pursued.

In addition to these specific questions, the more general questions of what the relationships are between individual active faults and regional tectonic structures, and between active faulting and seismicity in the Central and Eastern U.S. have received new emphasis. A resolution of those general questions would undoubtedly be helped by answers to the specific questions.

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TABLE 1. Radiocarbon ages of alluvial deposits used to date movement on the Meers fault.

Stratigraphic Unit	^{14}C Age	Laboratory No.	Stratigraphic Position	Material
East Cache Aluvium	70 ± 150	DIC-3165	near the floor of present stream channel	charcoal and carbonized wood
	310 ± 150	W-5533	same interval as above	clay-humus
	470 ± 150	W-5540	35-55 cm above bottom contact	soil-humus
	600 ± 50	DIC-3161	1.6 m above bottom contact	charcoal
Fault-related alluvium	1,280 ± 140	DIC-3167	beneath bottom contact	charcoal
	1,360 ± 100	DIC-3169	do	soil humus
	1,740 ± 200	W-5543	do	soil humus
Browns Creek Alluvium	9,880 ± 160	DIC-3179	70-90 cm above bottom contact	clay-humus
	12,240 ± 240	DIC-3170	25-30 cm above bottom contact	clay-humus
	13,670 ± 120	DIC-3166	5-30 cm above bottom contact	snails

[1]This sample is at least 1-1.5 m higher stratigraphically than the other two samples from this unit.

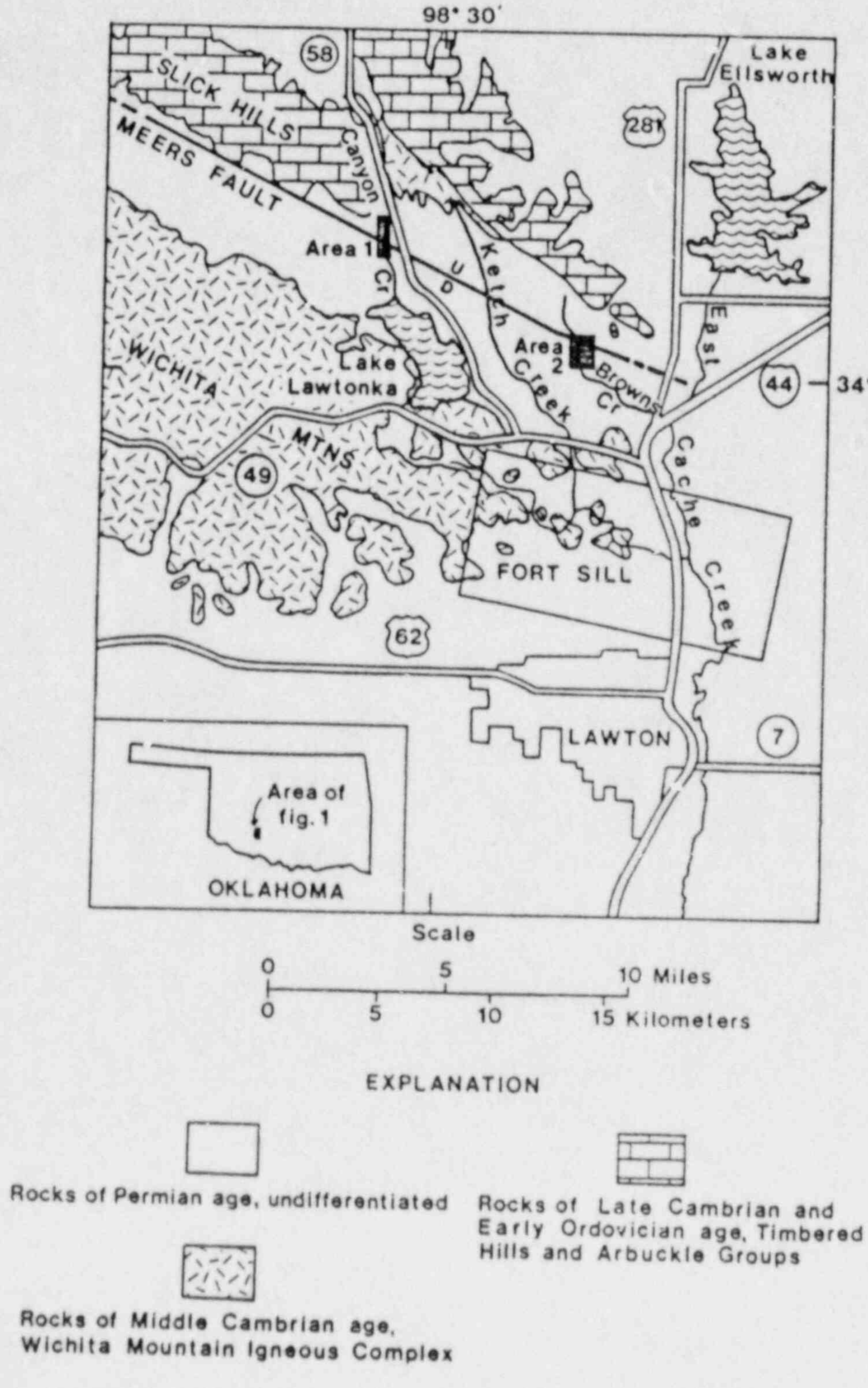

Figure 1. Generalized bedrock geologic map of the region, showing the location of the Meers fault and the two study areas. The trench sites are located in area 1.

Figure 2. Aerial view (looking north) of the Meers fault displacing Post Oak Conglomerate on the Kimbell Ranch (secs. 15, 16, T4N, R13W). Photograph by D. B. Slemmons, 1983.

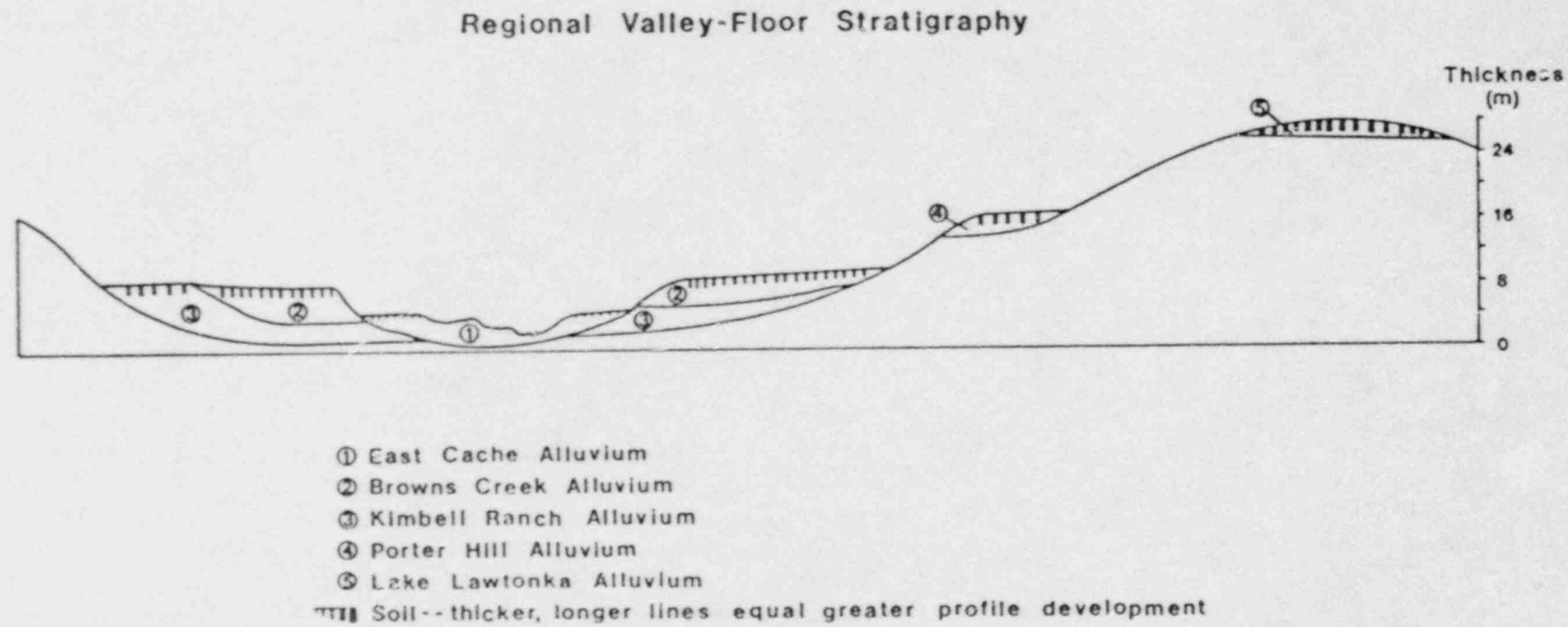

Figure 3. Schematic diagram showing stratigraphic relations of five allostratigraphic units present along the larger streams of the area.

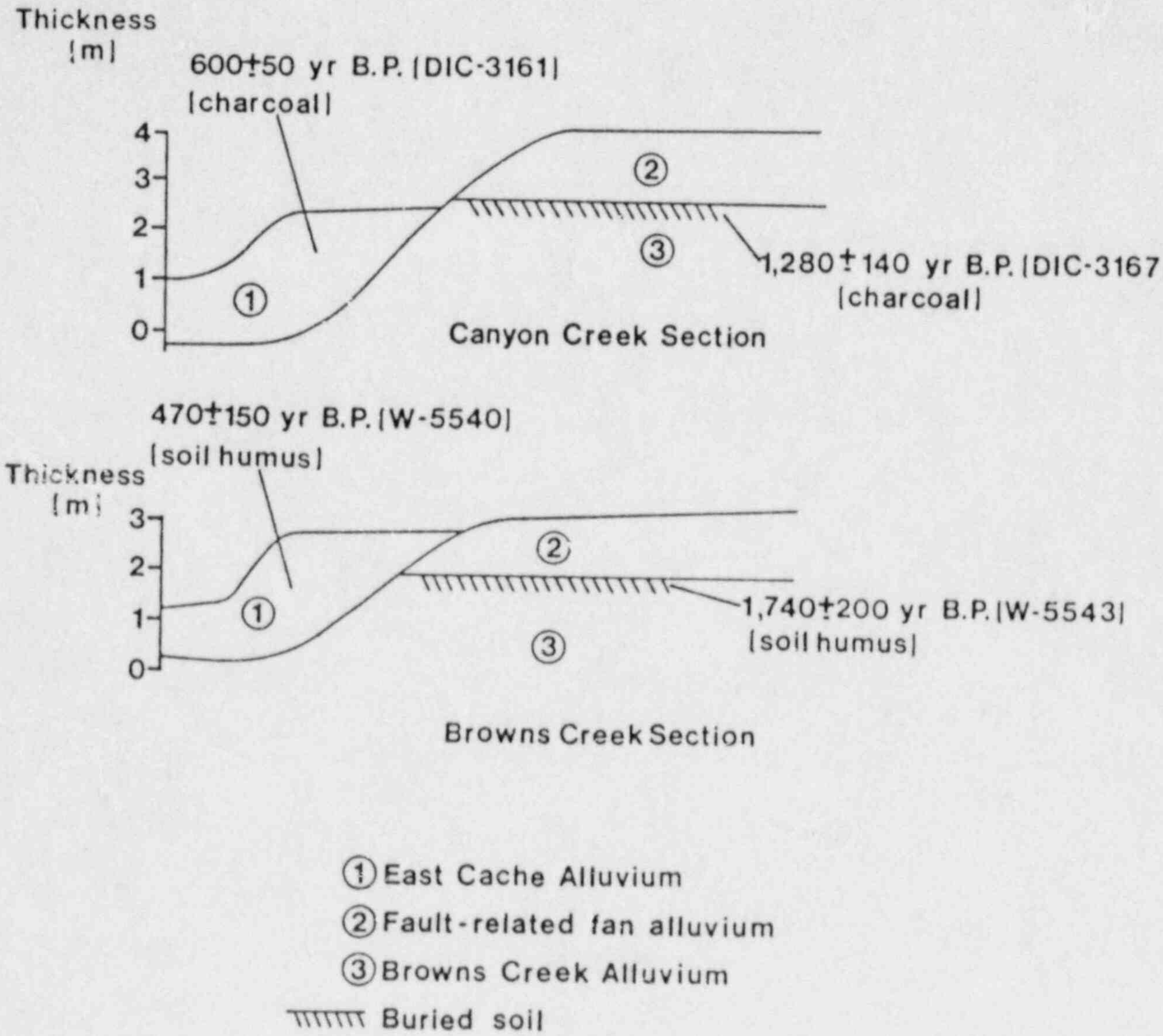

Figure 4. Schematic sections showing the stratigraphic relations and ^{14}C ages that provide limiting dates for the time of recent movement on the Meers fault.

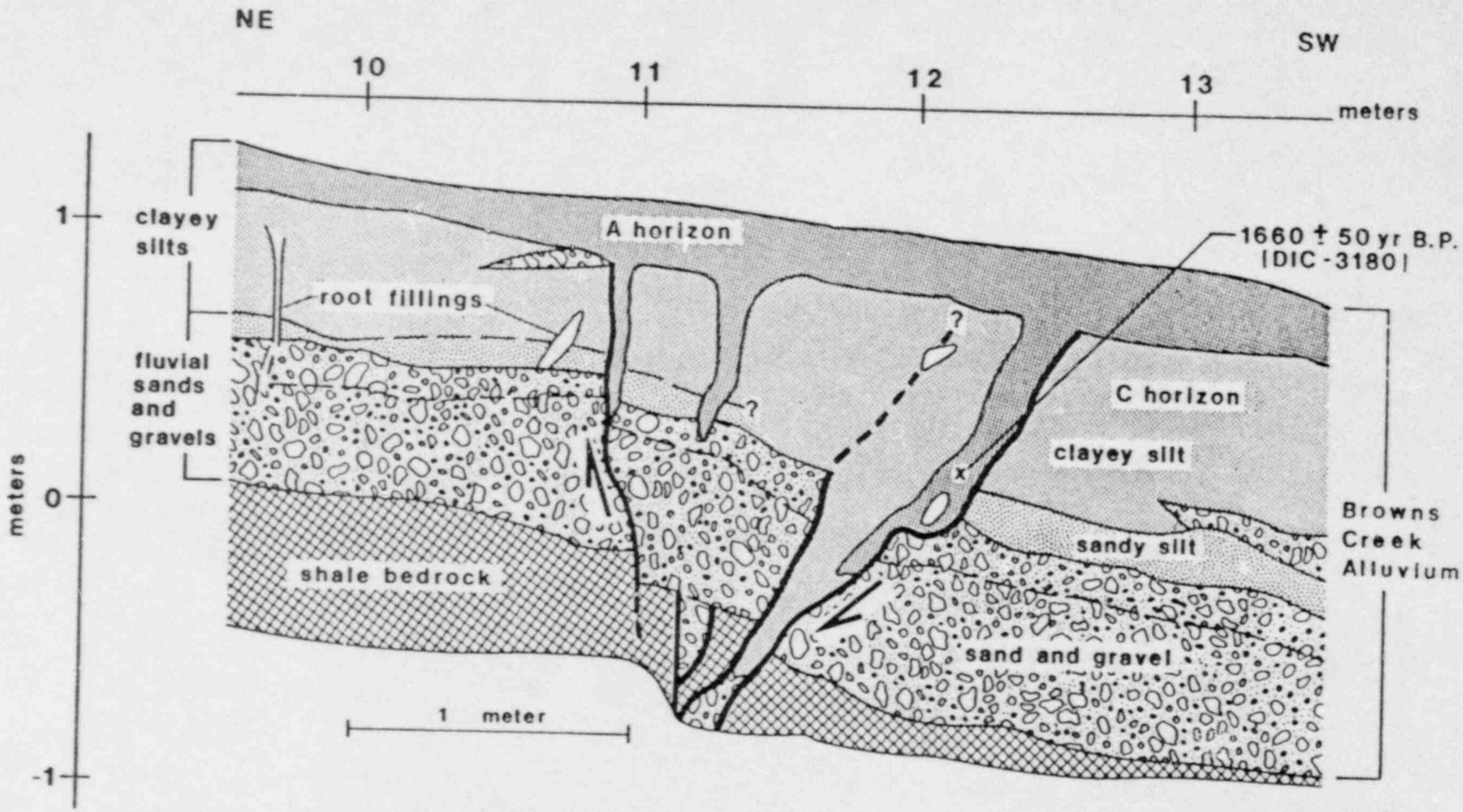

Figure 5. Part of the trench 1 log, showing stratigraphic relations near the main fault and location of ^{14}C age sample. Heavy lines are faults and edges of cracks that could be recognized by abrupt changes in the stratigraphy, dashed where inferred; arrows show general sense of displacement across the main fault zone. Fine lines are stratigraphic contacts, dashed where subtle.

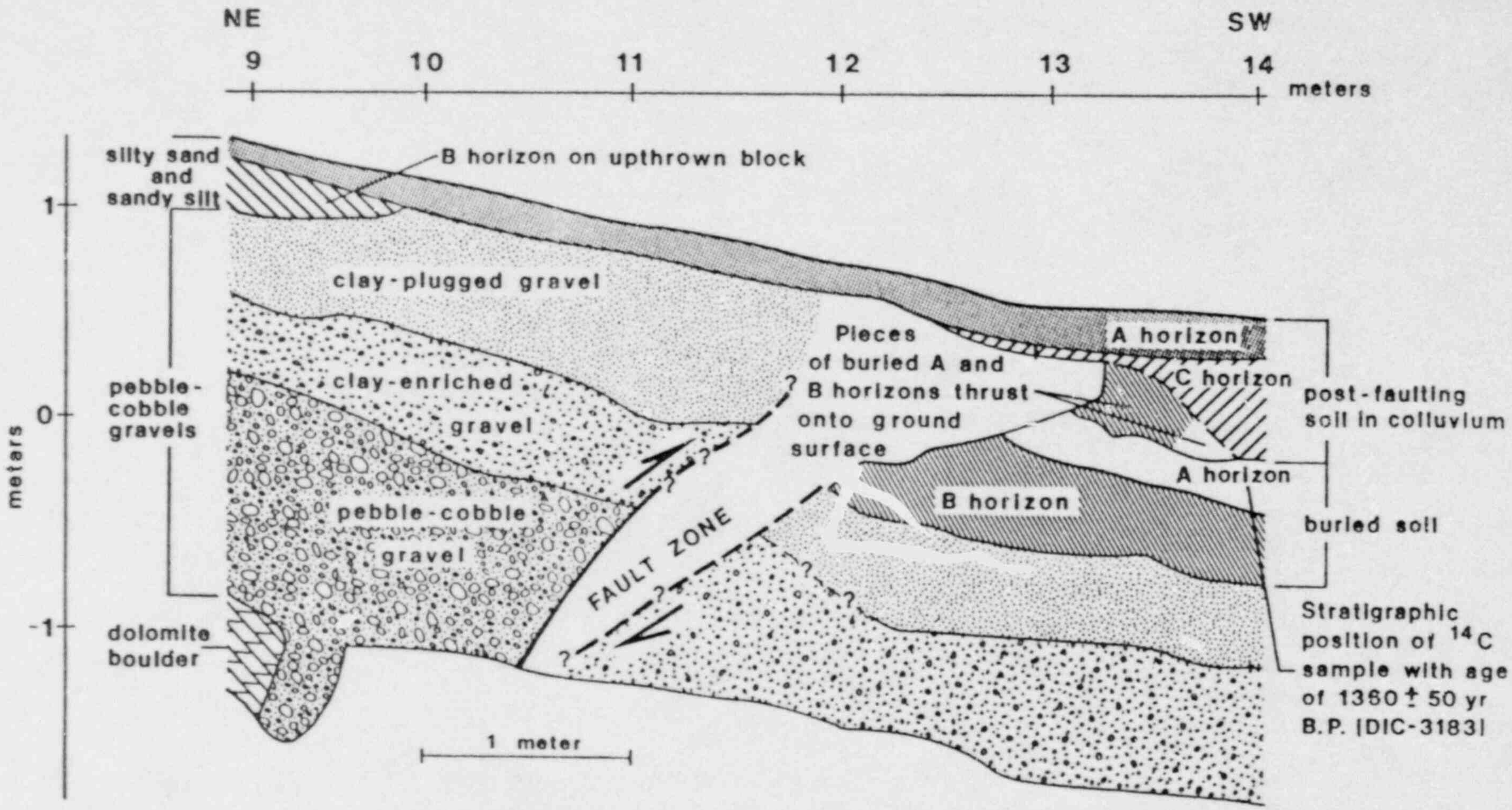

Figure 6. Part of trench 2 log, showing stratigraphic relations near the main fault zone. Heavy lines are faults that could be recognized by abrupt changes in the stratigraphy (dashed where inferred); arrows show general sense of displacement across the main fault zone. Fine lines are stratigraphic contacts (dashed where subtle).

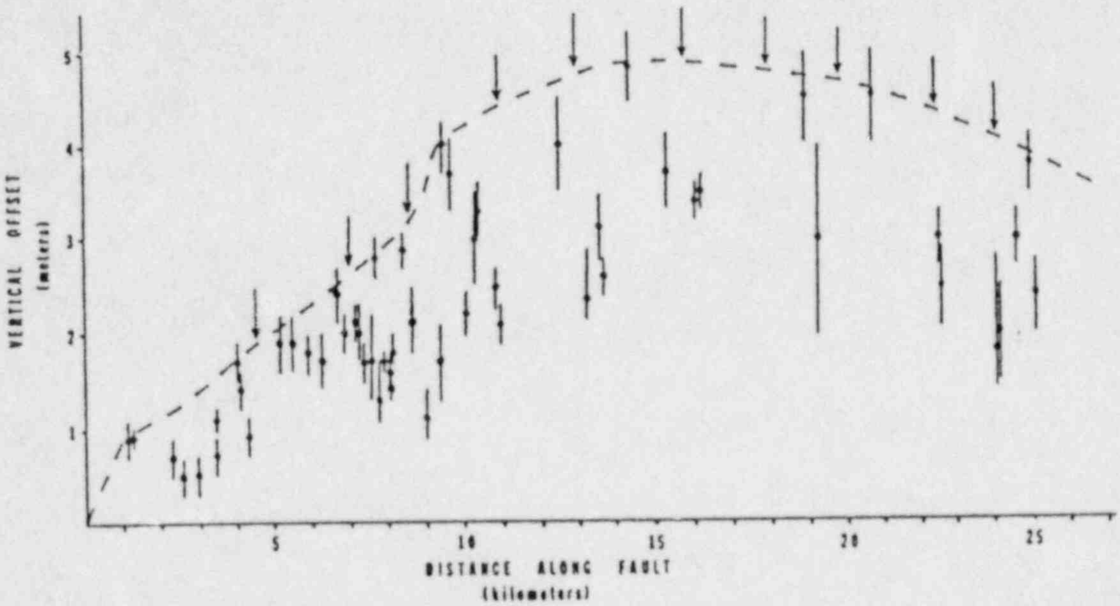

Figure 7: Graph of vertical component of Quaternary displacement, Meers Fault, from northwestern end to United States Highway 281. Locations of major streamlines are indicated by arrows. Enveloping surface represented by dashed line is taken to be a minimum approximation of displacement across the fault zone.