DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

In-Situ Stress Project,

Technical Report Number 4:

Summary of the Geologic Setting and Televiewer Logs from the Yongping Test Well, Yunnan Province, China

by

Springer, J.E.[1], Zhai Qingshan[2], Svitek, J.F.[1]

U.S. Geological Survey

Open-File Report 87-427

Prepared in cooperation with the State Seismological Bureau of China, the University of Wisconsin, and Stanford University.

[1] Menlo Park, CA

[2] Institute of Crustal Dynamics
Beijing, China

1987

CONTENTS

FIGURES

TABLES

SUMMARY OF THE GEOLOGIC SETTING AND TELEVIEWER LOGS FROM THE YONGPING TEST WELL, YUNNAN PROVINCE, CHINA

J.E. Springer, Zhai Qingshan, and J.F. Svitek

ABSTRACT

The Yongping well was drilled for earthquake research in a seismically active area of northwestern Yunnan Province. Major active faults in the area include NW-trending normal and right-lateral faults and NE-trending normal and left lateral faults. Analysis of the horizontal slip component on the major faults indicates that the area is undergoing WNW extension and that the maximum horizontal compressive stress is oriented NNE. This is in good agreement with recent geodetic measurements.

The well was drilled to a depth of 500 m in an alkali syenite intrusive. Two hundred fifty-three fractures were identified on borehole televiewer logs. Fracture frequency does not show a systematic trend with depth. Fracture orientations are similar to those found in the Xiaguan hole, although there is a larger degree of scatter. Northwest-striking fractures are roughly parallel to the major NW-trending faults and NE-striking fractures are roughly parallel to the NE-trending faults.

INTRODUCTION

Yongping was chosen as the second site for the joint Sino-U.S. in-situ stress measurement project. The project is a cooperative research venture between the Chinese Institute of Crustal Dynamics (ICD), the U. S. Geological Survey, the University of Wisconsin, and Stanford University. The measurements were carried out in the China Earthquake Prediction Test Site (Fig. 1), a 60,000 square kilometer area in Yunnan Province. This is a region of high relief and active normal and strike-slip faulting (Allen et al., 1984). Hydraulic fracturing stress measurements were performed in the 500 m-deep well, located located 10 km west of the town of Yongping (Fig. 2). Before stress measurements were performed, a borehole televiewer (BHTV) log was run in order to inspect the condition of the well bore, select intervals for hydraulic fracturing, and evaluate pre-existing fractures. In this paper, we summarize the tectonics of the area and present the results of in-situ fracture studies in the borehole.

The Yongping well was continuously logged with the BHTV. The orientation and distribution of fractures were determined from the log. These data were evaluated to determine the variations in fracture distribution with depth and what relation, if any, could be found between the observed fractures and what is known about the regional stress field and geologic history.

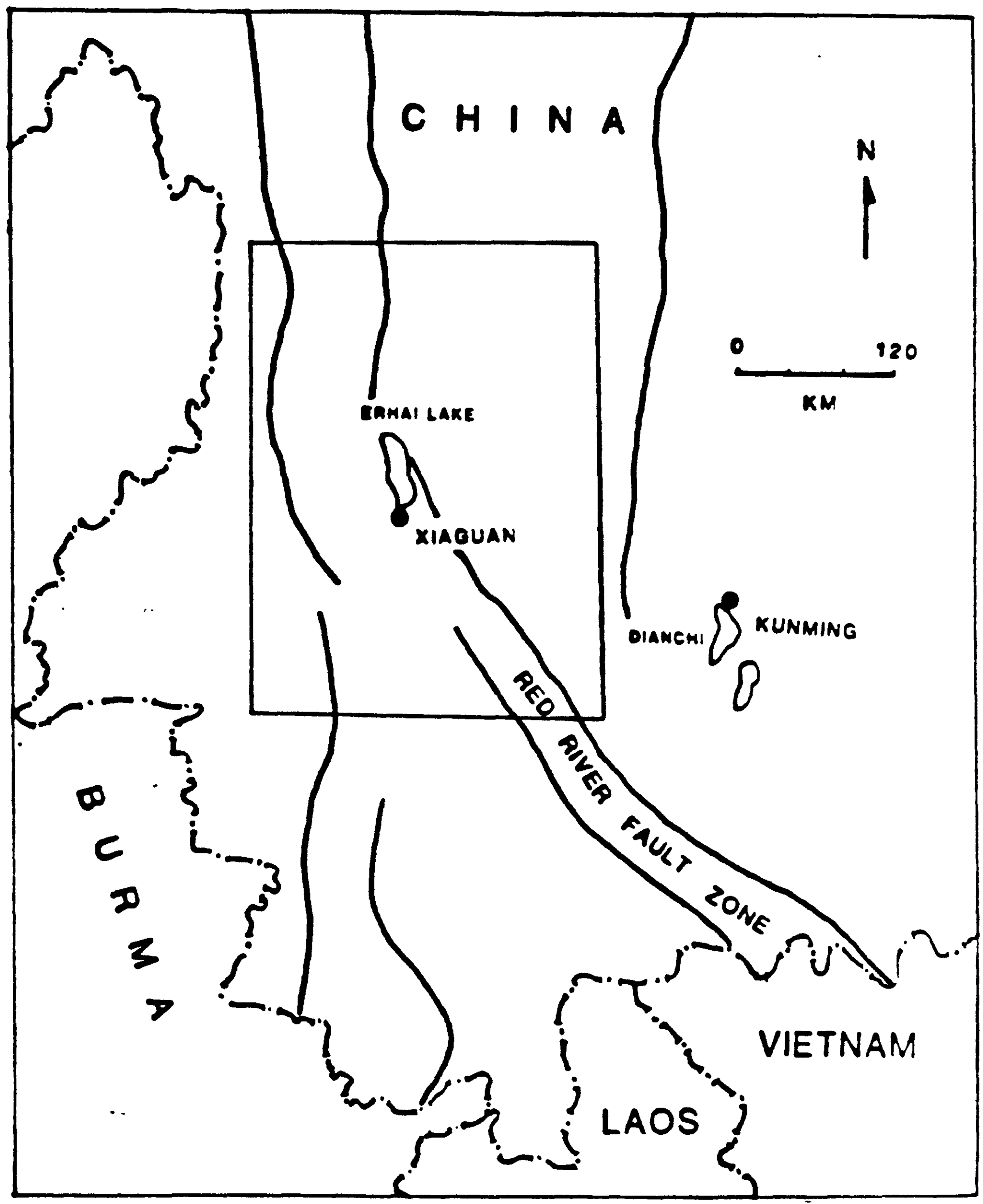


Figure 1. Location map showing the Earthquake Prediction Test Site in southwest China. The rectangle represents the area of figure 2.

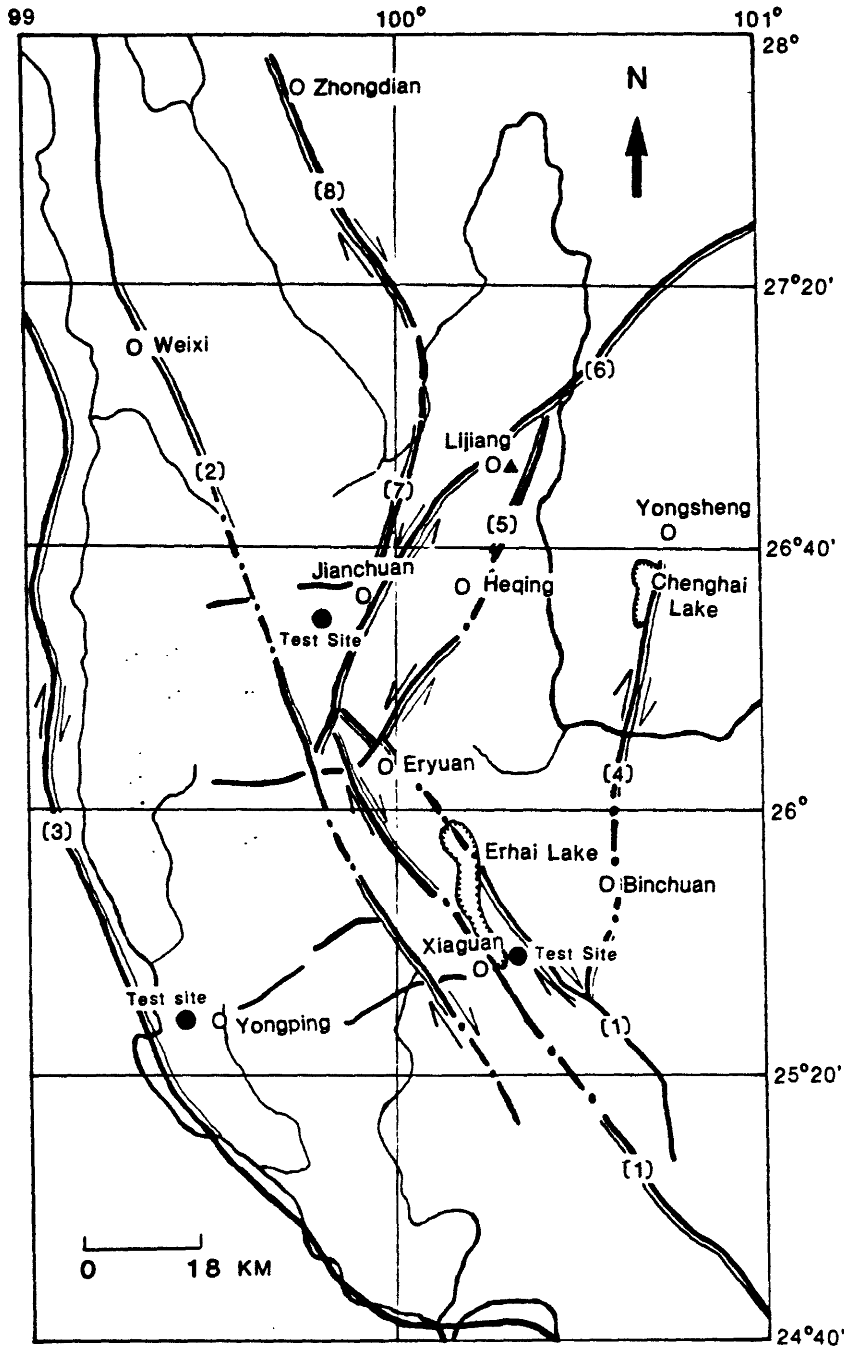


Figure 2. Map showing the main tectonic features of the area and location of the test well. Faults keyed by number on the map are: 1: Red River fault, 2: Madeng fault, 3: Lancang River fault, 4: Chenghai-Binchuan fault, 5: Heqing-Eryuan fault, 6: Lijiang fault, 7: Jianchuan fault, and 8: Zhongdian fault.

GEOLOGY AND TECTONICS

The region is dominated by two sets of active faults; NW-trending, normal and right lateral strike-slip faults associated with the Red River fault, and NE-trending normal and left-lateral faults (Fig. 2). Data on each of the eight faults identified in fig. 2 are shown in Table 1. Various local names have been applied to the faults, so the names given here may differ from those in other papers. Most of the faults have both normal and strike-slip components of motion. The ratios of vertical to horizontal slip vary along the strikes of faults. For example, the Red River fault (1) north of Xiaguan is primarily a normal fault, while south of Xiaguan it is primarily strike-slip.

TABLE 1
Major Faults in the Earthquake Prediction Test Site

No.	Name	Average trend	Sense of Slip and reference	Slip Rate (if known) and reference
1	Red River	N40W	Right-lateral and normal (Allen, 1984)	2 to 5 mm/y (Allen, 1984)
2	Madeng	N25W	Right-lateral (Liu et al., 1986)	_____
3	Lancang River	N25W-N30W	Right-lateral (Liu et al., 1986)	0.7 mm/y horizontal (ICD, 1985)
4	Chenghai-Binchuan	N10E	Right-lateral and normal (Yan et al., 1983)	_____
5	Heqing-Eryuan	N30E-N40E	Normal and left-lateral (Liu et al., 1986; Wu and Deng, 1985; Li et al., 1986)	_____
6	Lijiang	N30E-N50E	Left-lateral	2.34 mm/y horizontal (Yan et al., 1983)
7	Jianchuan	N20E	Normal (Wu and Deng, 1985)	_____
8	Zhongdian	N25W	Right-lateral (Liu et al., 1986)	_____

From the horizontal component of motion on the faults, a simple plane stress model was constructed (fig. 3). Faults with strikes between N70W and N20E have dextral motion and faults with strikes between N20E and S70E have sinistral motion. Based on the data in Table 1, the average maximum horizontal compression is oriented approximately N20E and the minimum horizontal compression is N70W. The Jianchuan fault (7) is perpendicular to the minimum horizontal stress and is almost pure normal with vertical movement of more than 1200 m in the Quaternary (Wu et al., 1985). Triangulation surveys across the Chenghai-Binchuan fault (4) (Yan et al., 1983) indicate extension in a N56W direction and maximum shortening in a N34E direction. This is slightly different from, but generally consistent with the stress directions shown in fig. 3. The region is therefore undergoing WNW to NW extension and NNE to NE maximum compression.

Local Geology

The well was drilled in an alkali syenite intrusive (Fig. 4) to a depth of 500 m. A lithologic summary of the hole is shown in figure 5. The nearest major fault is the Lancang River fault (3), an active right-lateral strike-slip fault with a slip-rate of 0.7 mm/y (ICD, 1985). Several northwest-trending normal faults run through the area. One of these is exposed 2 km west of the drill hole. It is uncertain whether this fault cuts across the intrusive. Another northwest-trendint fault is exposed about 1 km south of the well. Its mapped trace terminates in this vicinity, although it may extend farther to the northwest (fig. 4).

FRACTURE STUDIES

The BHTV (Zemanek et al., 1969) was run in the hole to determine the location, orientation, and distribution of natural fractures. The BHTV system consists of a downhole logging tool and surface instruments. The tool is a centralized logging sonde with a rotating acoustic piezoelectric transducer. The transducer emits 1 MHz pulses focused in a 3 degree beam at a rate of about 1800 pulses per second. It rotates at three revolutions per second as the tool is logged upward at a speed of 1.5 m per minute. A flux-gate magnetometer provides orientation with respect to magnetic north. The acoustic pulses from the transducer are reflected off the borehole wall back to the transducer which then acts as a receiver. The signal is sent through the logging cable to the surface for recording and processing. The amplitude of the reflected pulse is displayed as a function of brightness on a three-axis oscilloscope. Each sweep on the scope is triggered to magnetic north and the display is photographed as successive sweeps move up the scope. The resulting log is a sonic picture of the inside of the hole as if it were split down the middle and laid flat (fig. 6a). The raw wave forms are also recorded on video tape.

Resolution of the image depends on hole diameter, wall roughness, and the acoustic impedence contrast between the bore hole fluid and the wall rock. Where the smoothness of the well

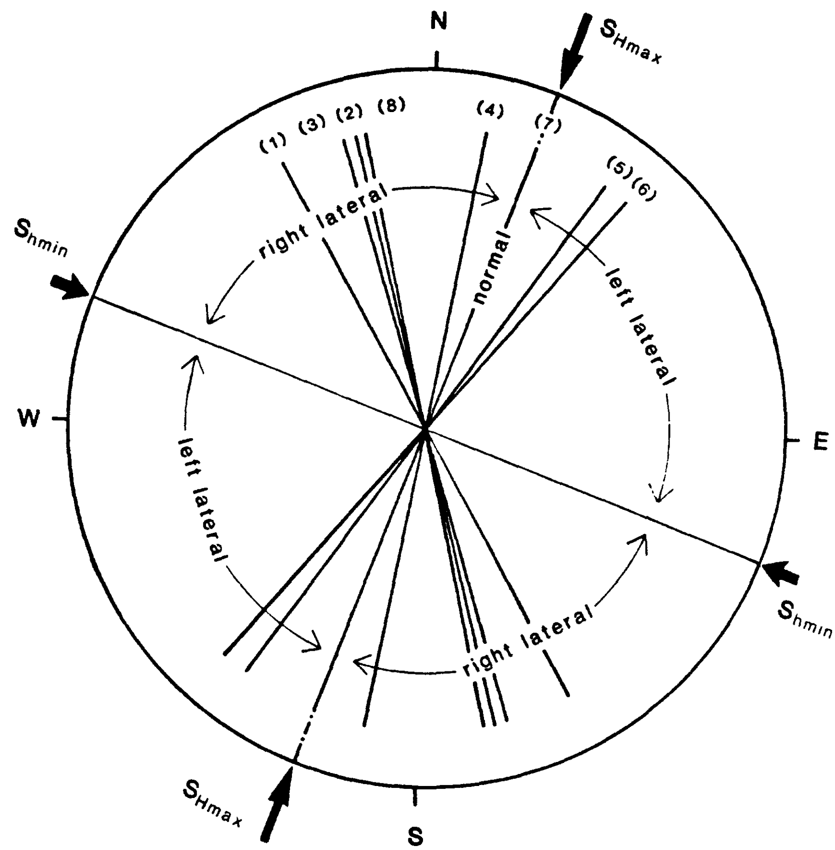


Figure 3. Diagram showing the horizontal slip component on major faults and inferred axes of greatest and least horizontal compression. Numbers on the faults are keyed to the names in fig. 2.

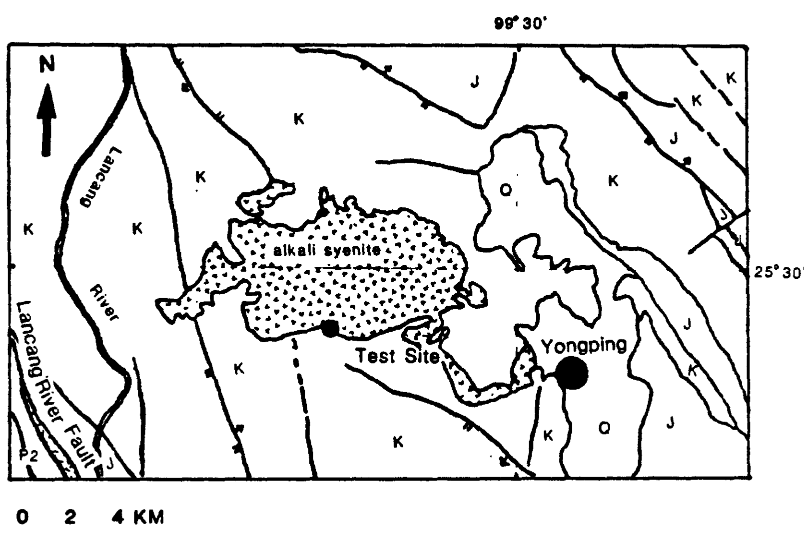


Figure 4. Geologic map of the vicinity of the Yongping drill hole.

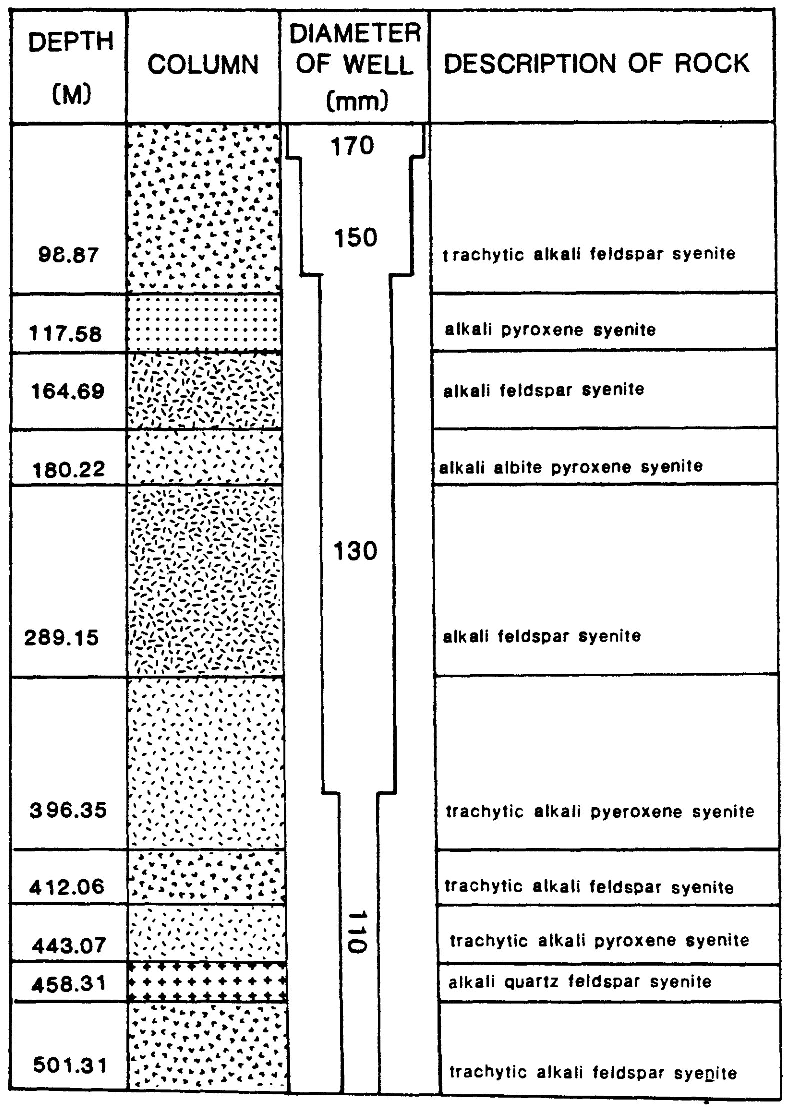


Figure 5. Lithologic summary of the Yongping drill hole.

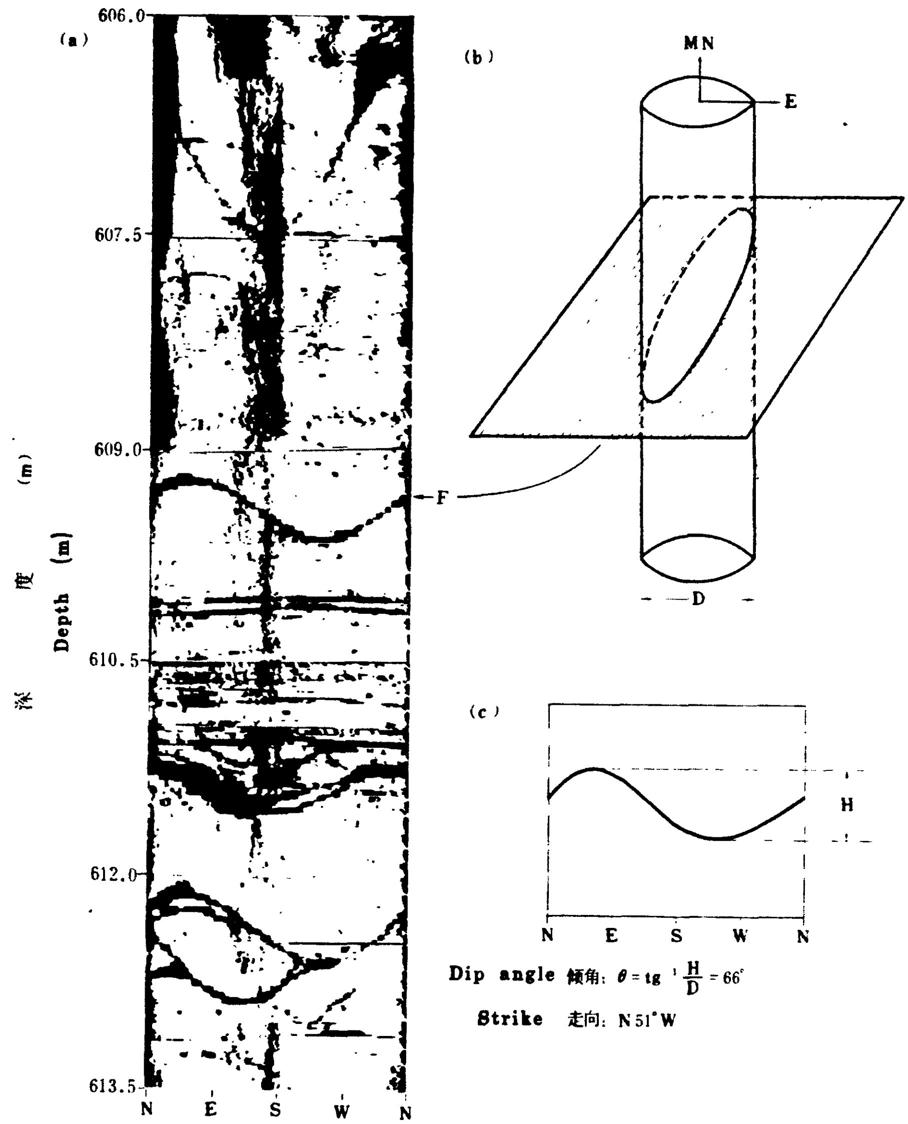


Figure 6. Typical BHTV log and schematic diagrams representing an inclined fracture crossing the well.

bore is perturbed by a fracture, a dark pattern appears on the log. If it is an inclined fracture, it shows up as a sinusoid on the log (fig. 6b and c). Because the oscilloscope is triggered on magnetic north, the orientation of the sinusoid can be determined from the televiewer picture (see Zemanek et al., 1969; Springer et al., 1987). The horizontal and vertical scales are different on the log. For a hole the size of the Yongping well, there is an approximate 4:1 horizontal exaggeration which causes the sinusoidal fracture to appear flattened.

The BHTV was run continuously from 488 m to 120 m. The complete log is shown in the Appendix. A total of 253 fractures were identified on the log. A plot of fracture frequency as a function of depth is shown in fig. 7. The left-hand plot shows the observed fracture frequency. Because steeply-dipping fractures have a lower probability of intersecting a vertical borehole, the fracture frequencies were corrected for dip by multiplying each observation by 1/cos (dip angle) and summing the results. This corrected frequency is shown on the right-hand side of fig. 7. The left-hand plot is representative of the fractures observed in the well and the right-hand plot reflects the degree of fracturing in the rock mass.

The plot on the right has larger frequencies, due to the weighted influence of the high-angle fractures. The relative sizes of the class intervals, however are essentially the same as those in the left-hand plot. This means that the relative abundances of high- and low-angle fractures do not change significantly throughout the hole.

A series of lower hemisphere equal-area plots of poles to fractures is shown in fig. 8. The entire logged section is presented in fig. 8 (a). Depth intervals centered around the frequency maxima of fig. 7 are shown in fig. 8 (b), (c), (d), and (e). The entire population (fig. 8a) is highly scattered and while there are more poles in the northwest quadrant, the trend is not strong. In the interval from 120 m to 183 m, the orientations are similarly scattered although one clear cluster has an ENE strike and steep southeast dip. Between 183 m and 244 m, a pattern begins to emerge. Most of the fractures have strikes between NNW and WNW and two clusters appear; one has southwest dips and the other has northeast dips. Between 244 m and 366 m, the southwesterly dipping cluster dominates. Below 366 m, the orientations change. The majority of the fractures dip to the southeast and have strikes between N-S and NE.

The fracture orientations are similar to those found above 378 m in the Xiaguan hole (Springer et al., 1987), although the amount of dispersion is greater. Northwest-striking fractures are subparallel to the Lancang River fault and related faults. North-south- and northeast-striking faults are subparallel to the more northerly striking faults in the region (Figs. 2 and 3). The high degree of scatter in these data, however, make the correlations somewhat speculative.

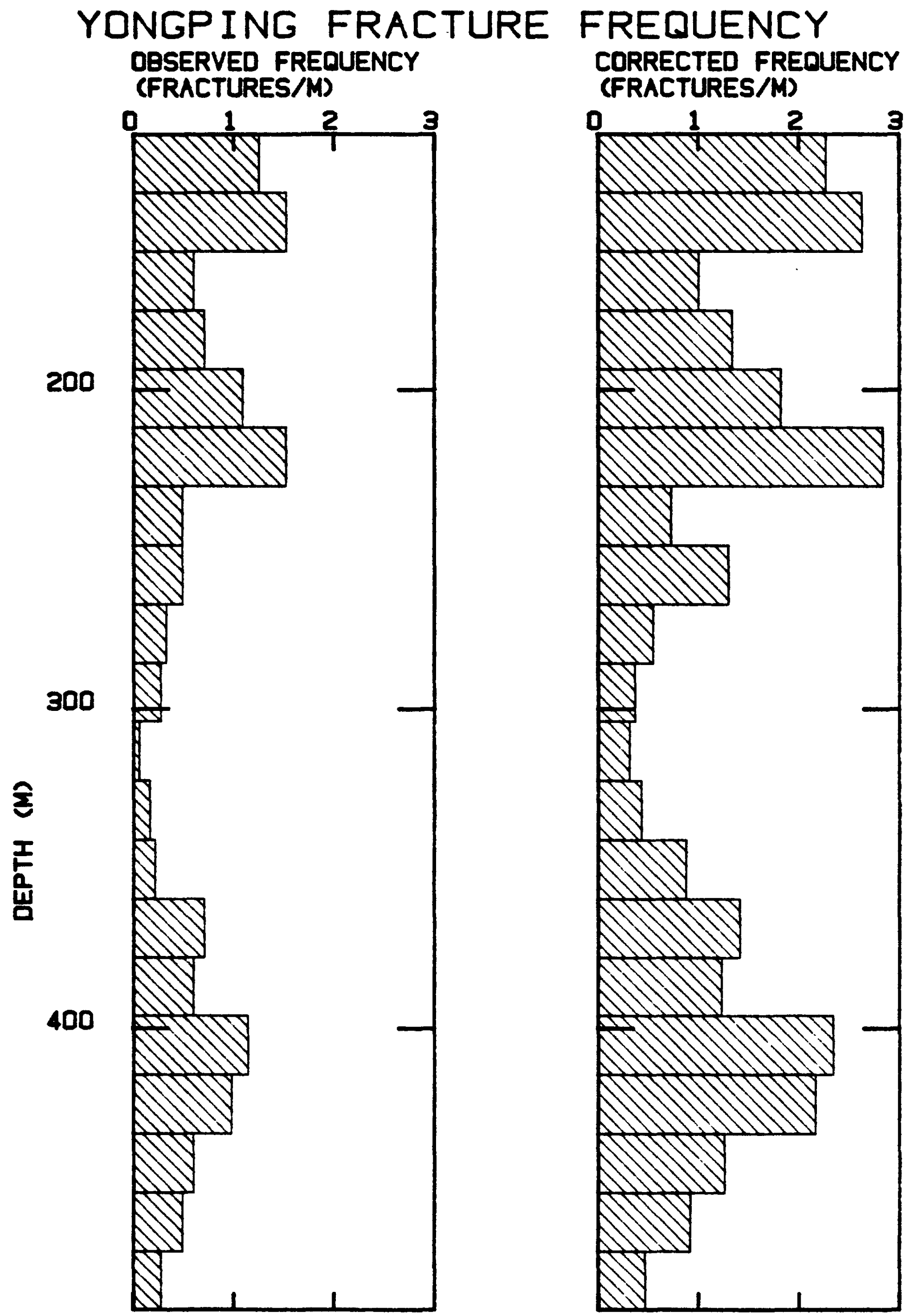


Figure 7. Fracture frequency as a function of depth. The left-hand plot is the observed frequency and the right-hand plot is the frequency after correcting for the bias of the borehole orientation.

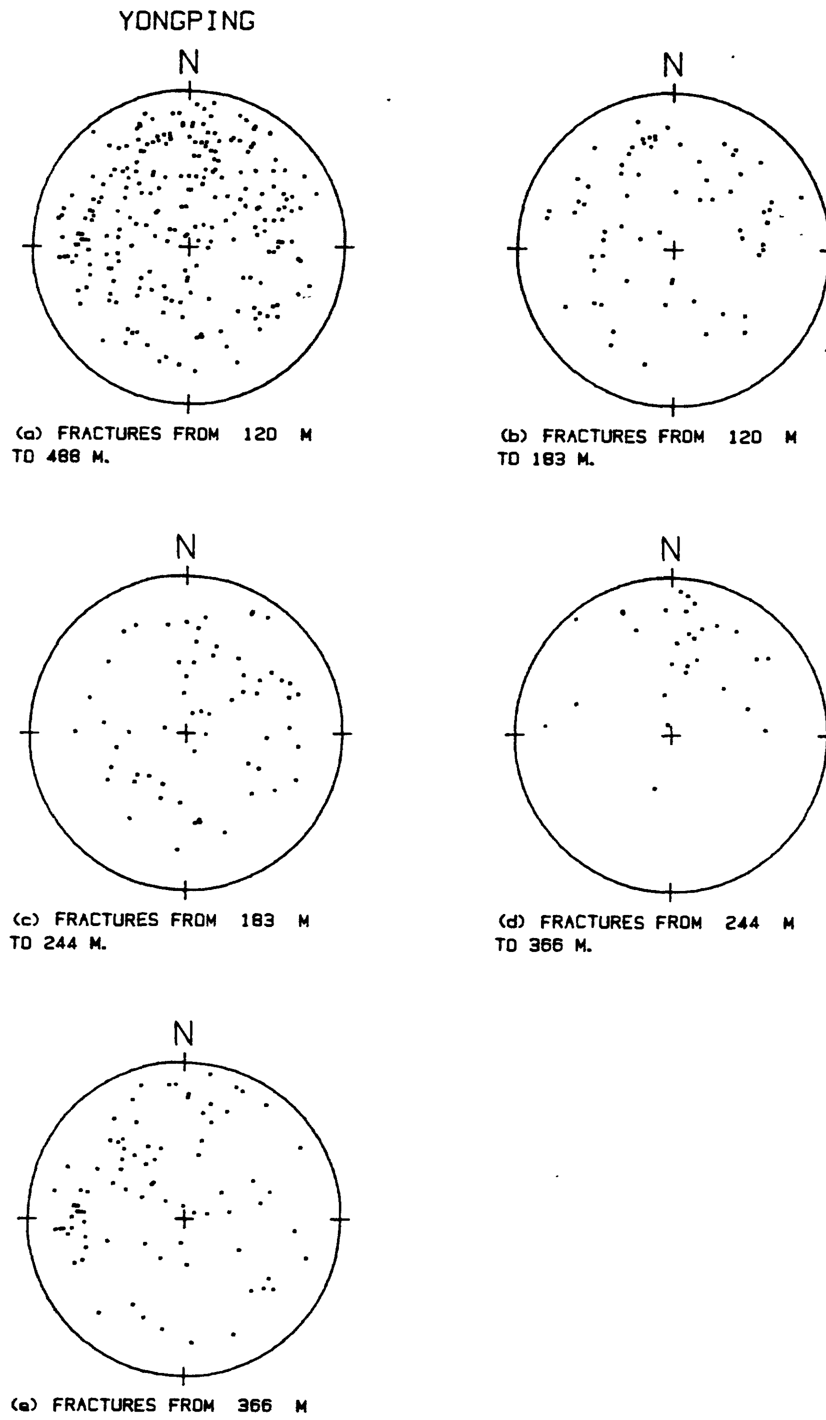


Figure 8. Lower hemisphere schmidt projections of poles to the fractures seen on the BHTV log. (a) shows all the fractures. (b), (c), (d), and (e) show fractures in the indicated depth intervals.

CONCLUSIONS

The Yongping well is located in a tectonically active area of northwestern Yunnan province that contains northwest-trending normal and dextral faults and northeast-trending normal and sinistral fault. The horizontal component of slip on these faults is in fair agreement with geodetic data by Yan et al. (1983) and indicates that the region is undergoing WNW to NW extension. The average maximum horizontal stress and the axis of maximum shortening is oriented NNE to NE.

Two hundred fifty-three fractures were identified on the BHTV log and these indicate two northwest-striking sets, and a northeast-striking set. These fractures are similar to those found in the upper 378 m of the Xiaguan well, although the degree of scatter is much greater.

ACKNOWLEDGEMENTS

We thank Jack Healy, Mark Zoback, Bezalel Haimson, and Li Fangquan for their support and encouragement of the project. Zhao Guozhu helped run the televiewer log and provided geologic information. Doug Myren reviewed the manuscript and made helpful suggestions.

REFERENCES

Allen, C.R., Gillespie, A.R., Han Yuan, Sieh, K.E., Zhang Buchan, and Zhu Chengnan, 1984, Red River and associated faults, Yunnan Province, China; Quaternary geology, slip rates, and seismic hazard: Geological Society of America Bulletin, v.95, no.6, pp.686-700.

ICD, 1985, Second Sino-American hydraulic fracturing stress operation in the earthquake prediction site, west Yunnan Province: (In Chinese) 1985 annual report, 16p.

Li Xianggen, Ran Yongkang, Peng Gui, Zhang Jing, Guo Shunmin, Xiang Hongfa, Chen Tieniu, Zhang Guowei, Ji Fengju, and Ye Yongying, 1986, Active faults and thier relationship with seismic activities in Dali of Yunnan Province and its adjacent regions: (in Chinese) Seismology and Geology, v.8, no.4, pp.51-61.

Liu Guangxun, Li Fangquan, and Li Guirong, 1986, Active tectonics and state of stress in seismic region of northwest Yunnan Province, China: (in Chinese and English) Seismology and Geology, v.8, no.1, 14p.

Springer, J.E., Zhai Qingshan, M.D. Zoback, and Li Fangquan, 1987, Analysis of fractures from televiewer logs of a 500 m-deep well at Xiaguan, Yunnan Province, China: U.S. Geological Survey, open-file report, in press.

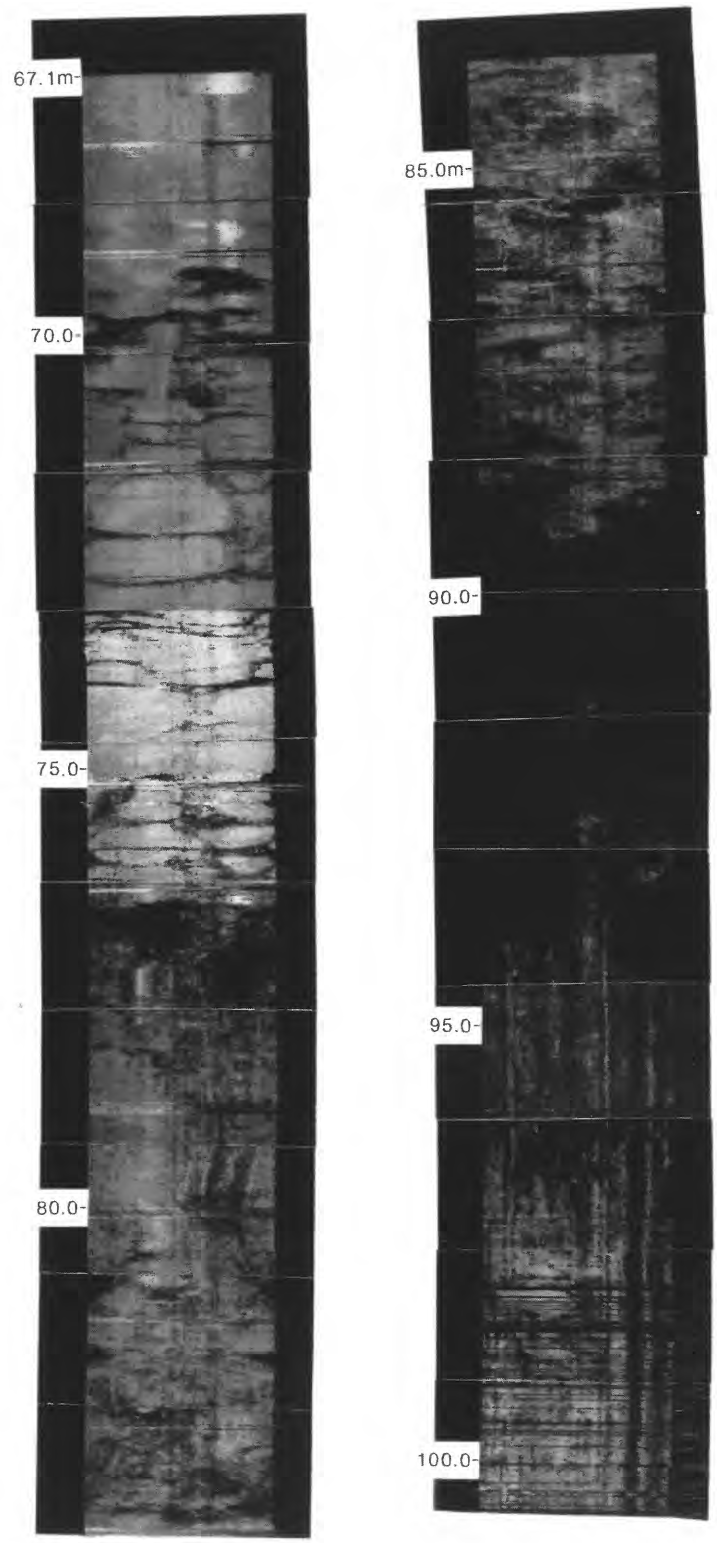
Wu Daning and Deng Qidong, 1985, Primary behavior of northwest Yunnan: Tectonic subsidence area and mechanics: (in Chinese) Modern Crustal Movement Research, v.1, pp.118-132.

Yan Shihua, Huang Kun, and Zhang Zusheng, 1983, Analysis of the horizontal deformation in Xiaguan-Weishan, Yunnan Province: (in Chinese) Journal of Seismological Research, v.6, pp.477-

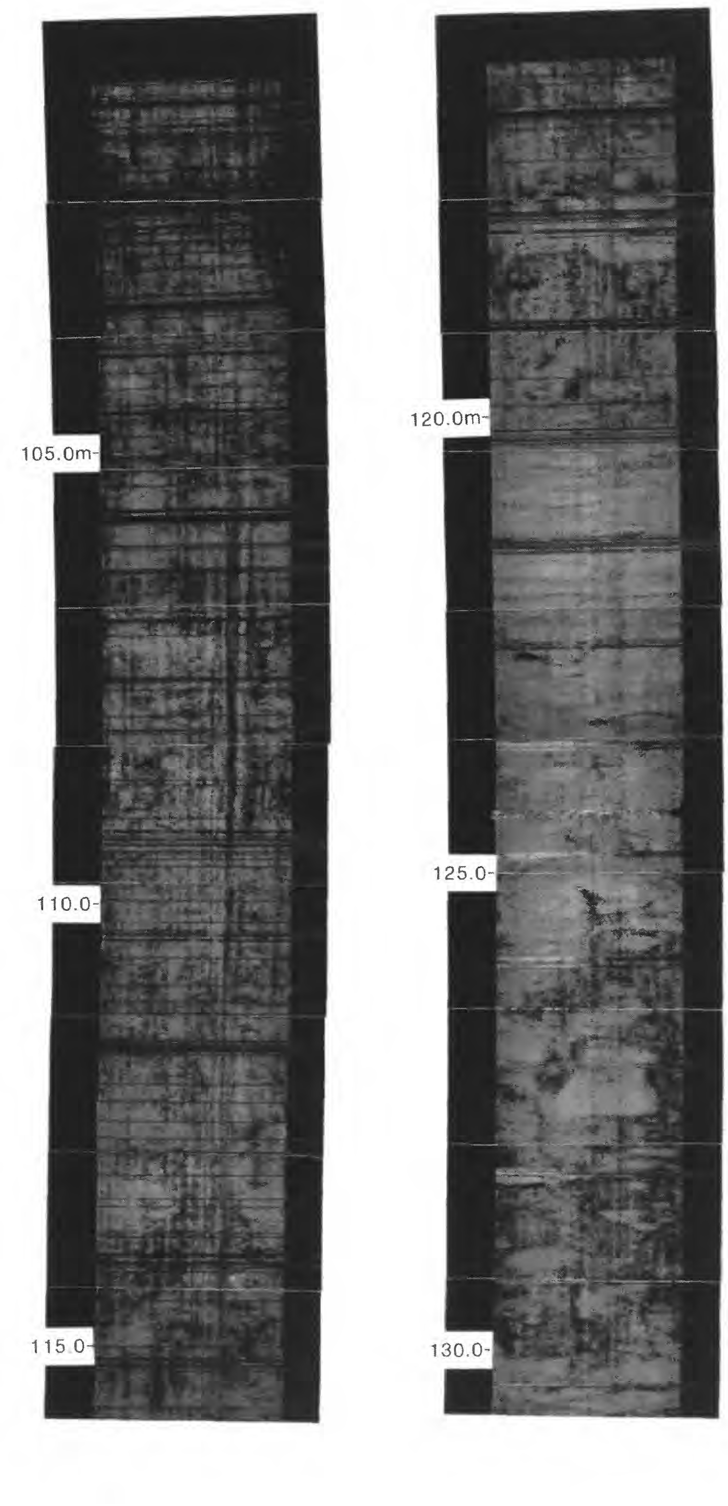
486.
Zemanek, J., R.L. Caldwell, E.E. Glenn, Jr., S.V. Holcomb, L.F. Norton, and A.D.J. Strauss, 1969, The borehole televiewer - a new logging concept for fracture location and other types of borehole inspection: Journal of Petroleum Technology, v.264, pp.762-774.

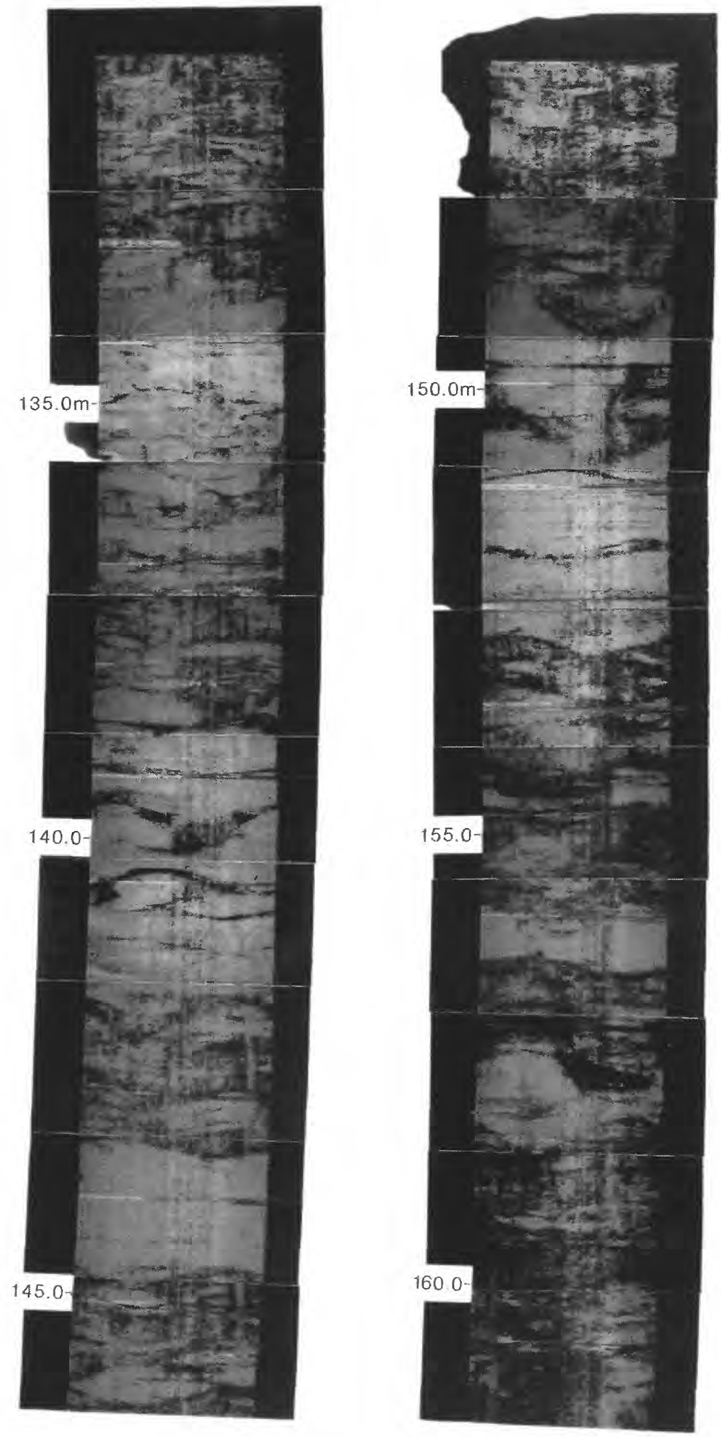
APPENDIX

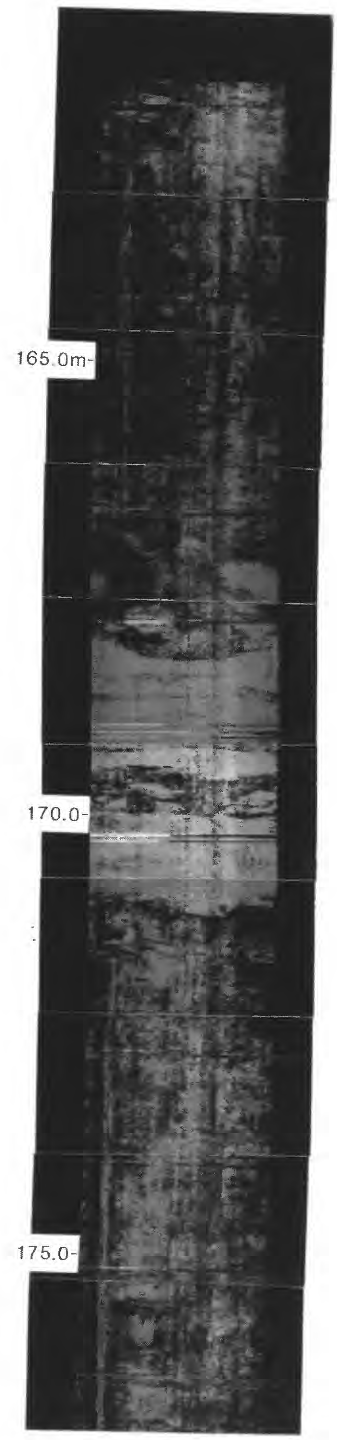
Televiewer Log of the Yongping Well

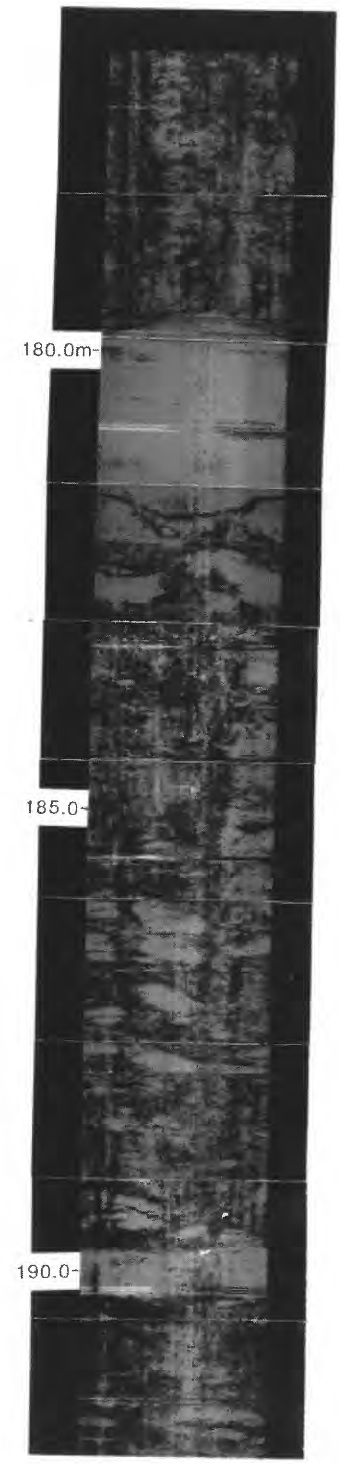


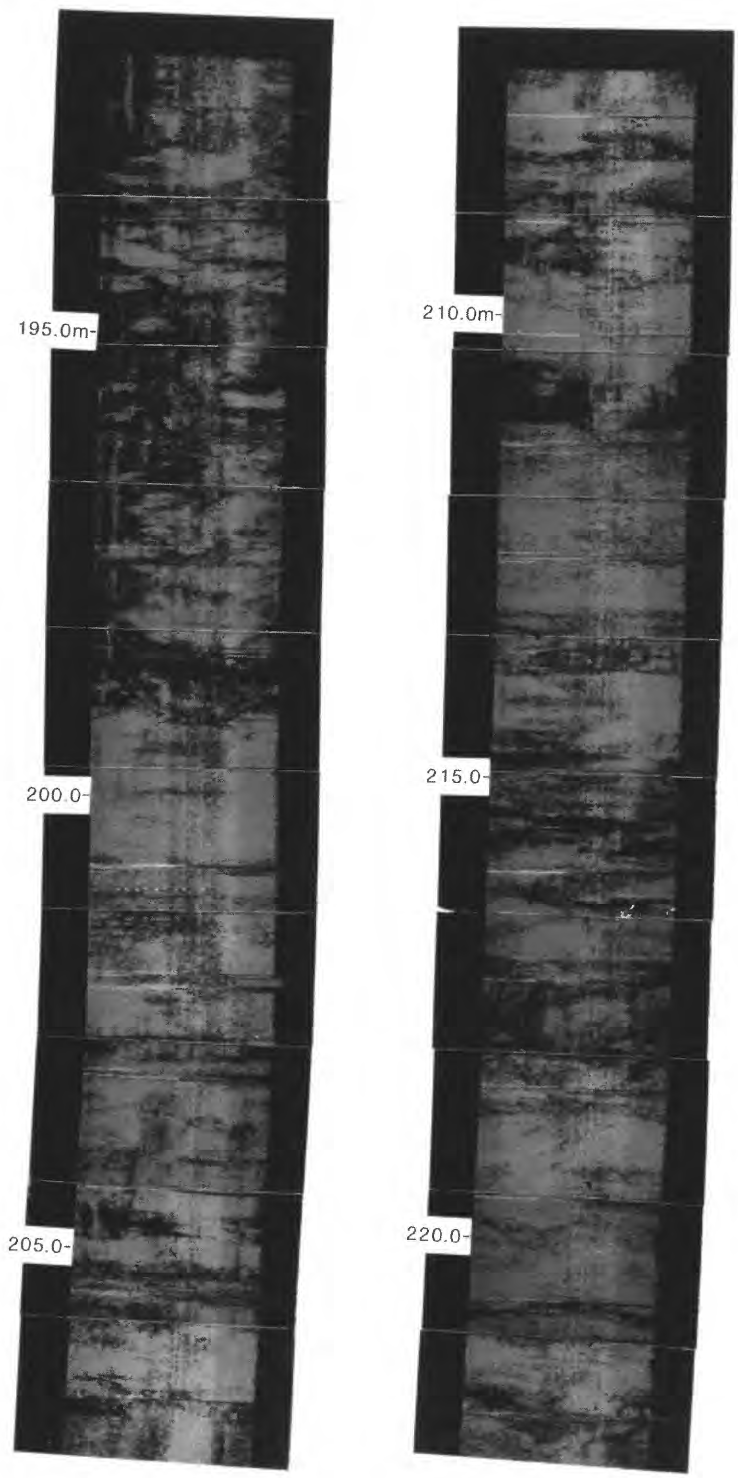
67.1m-
70.0-
75.0-
80.0-
85.0m-
90.0-
95.0-
100.0-

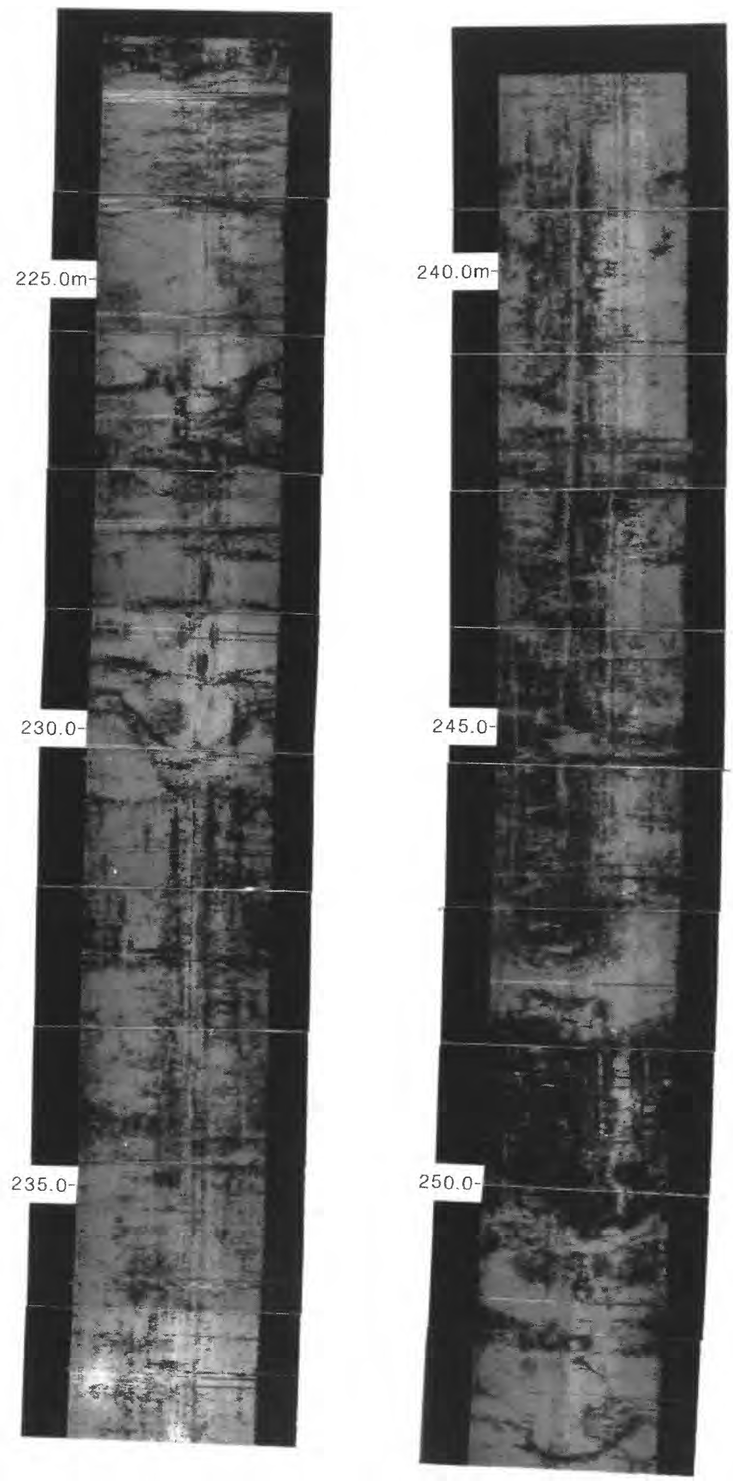

105.0m-
110.0-
115.0-
120.0m-
125.0-
130.0-

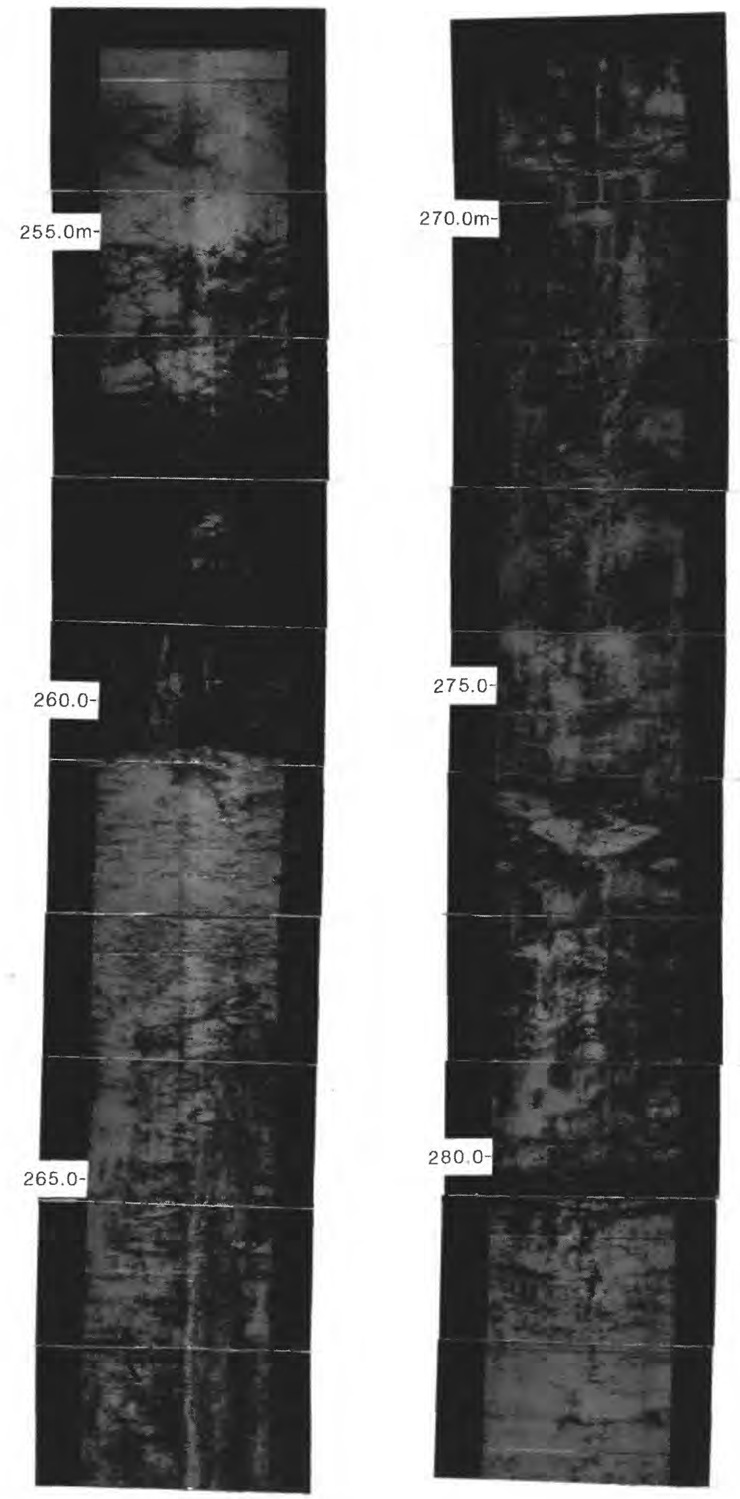

135.0m
140.0
145.0
150.0m
155.0
160.0

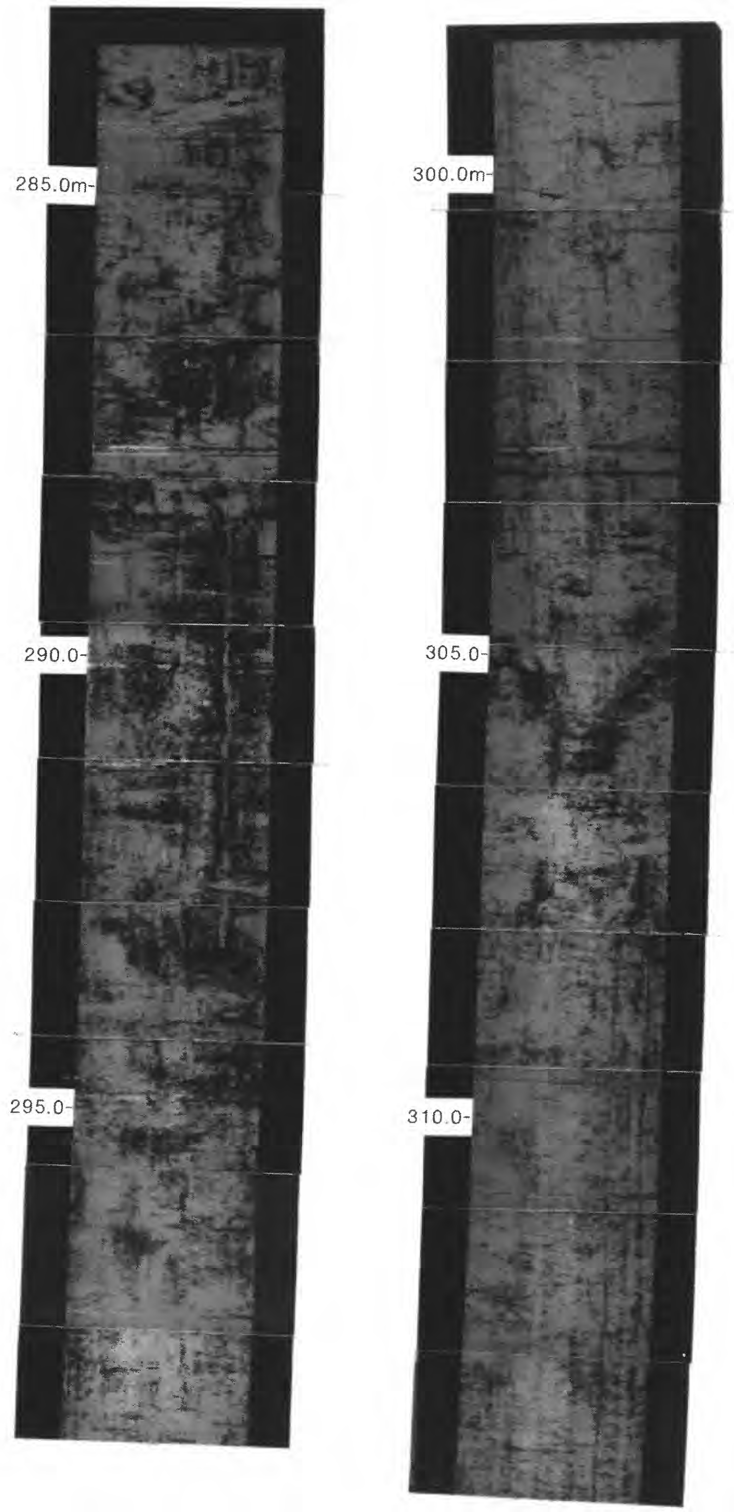

165.0m-
170.0-
175.0-

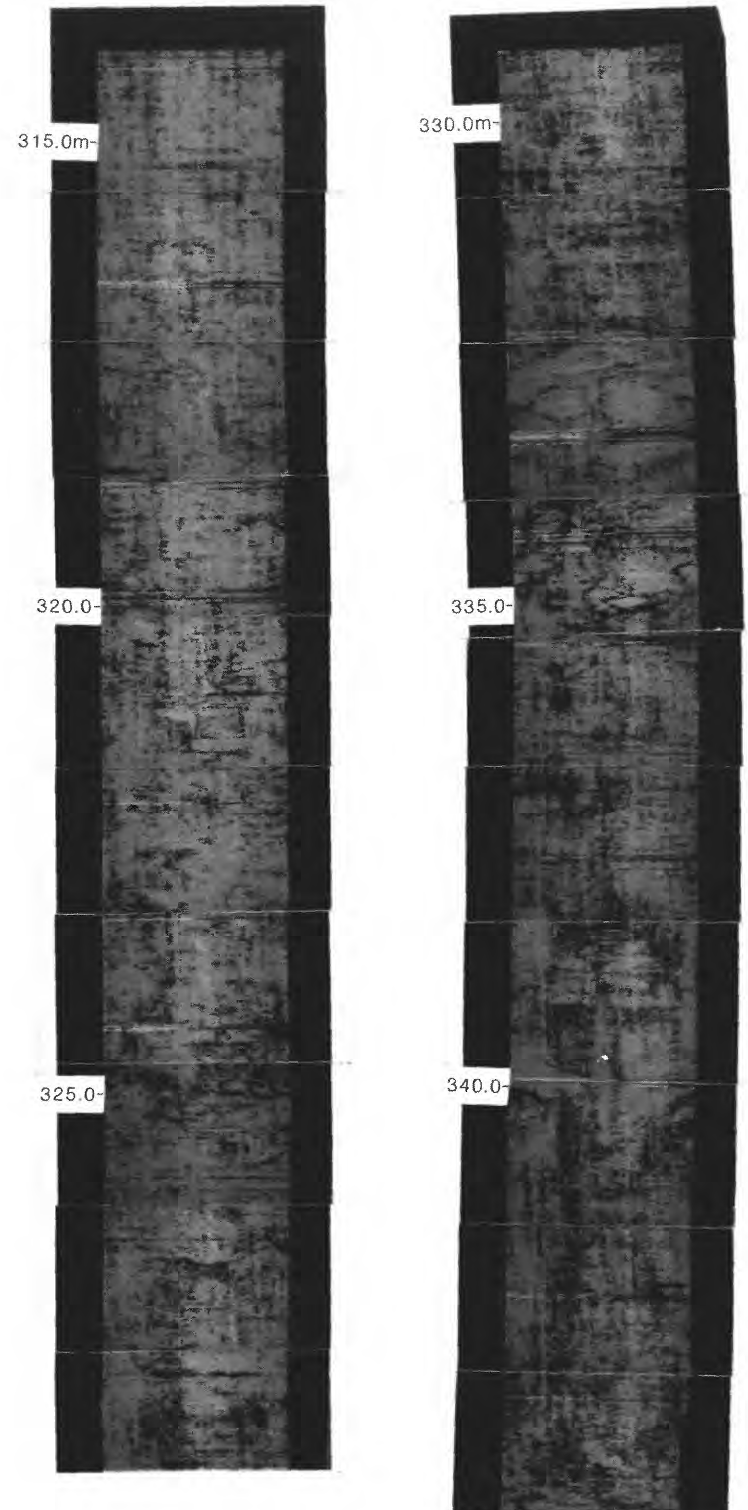

180.0m-
185.0-
190.0-

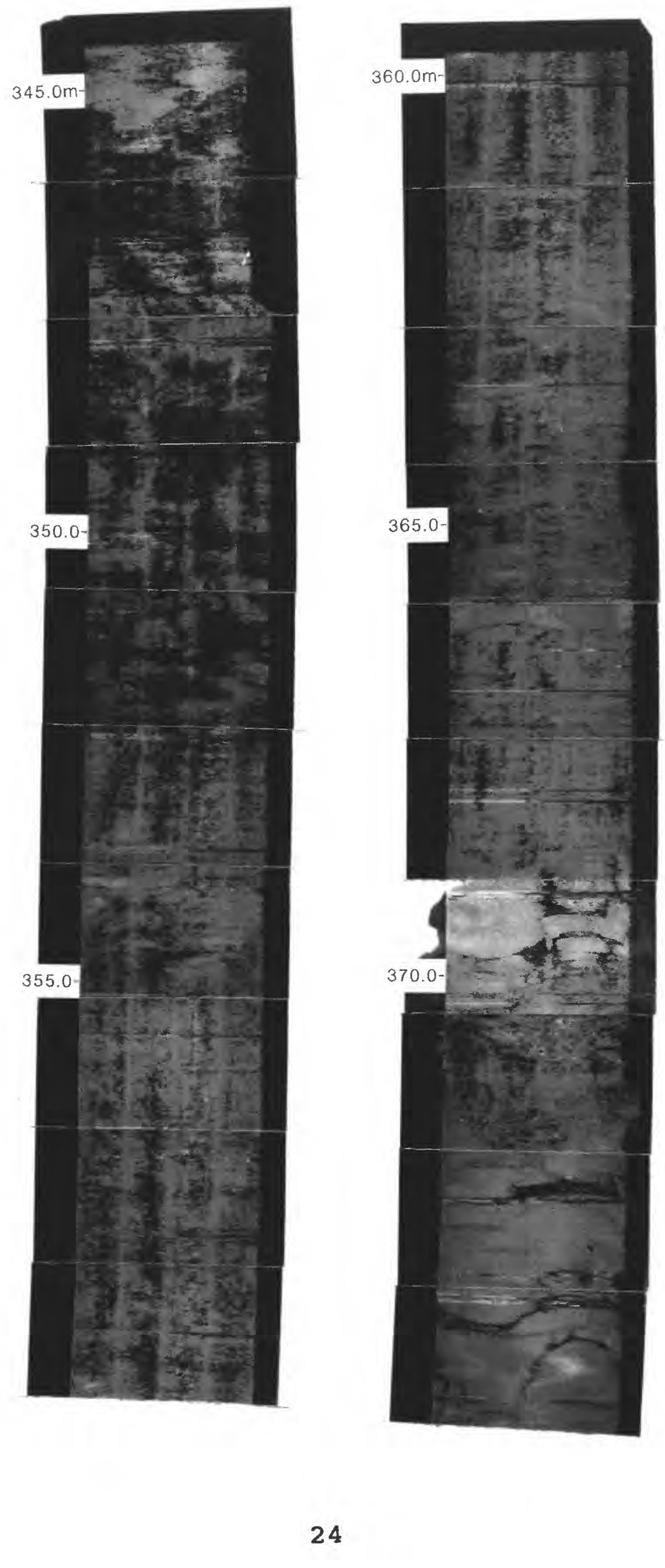

195.0m-
200.0-
205.0-
210.0m-
215.0-
220.0-

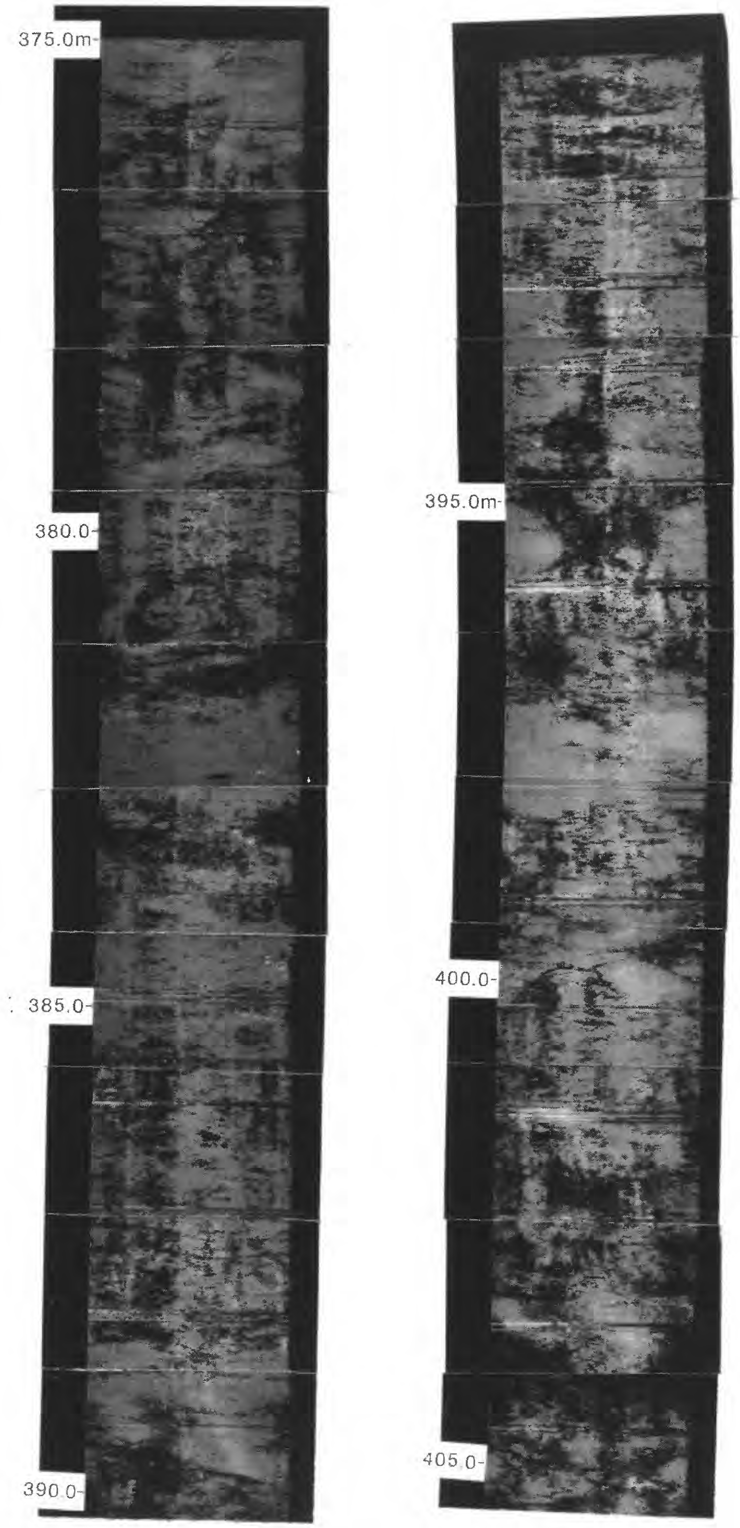

225.0m
230.0
235.0
240.0m
245.0
250.0

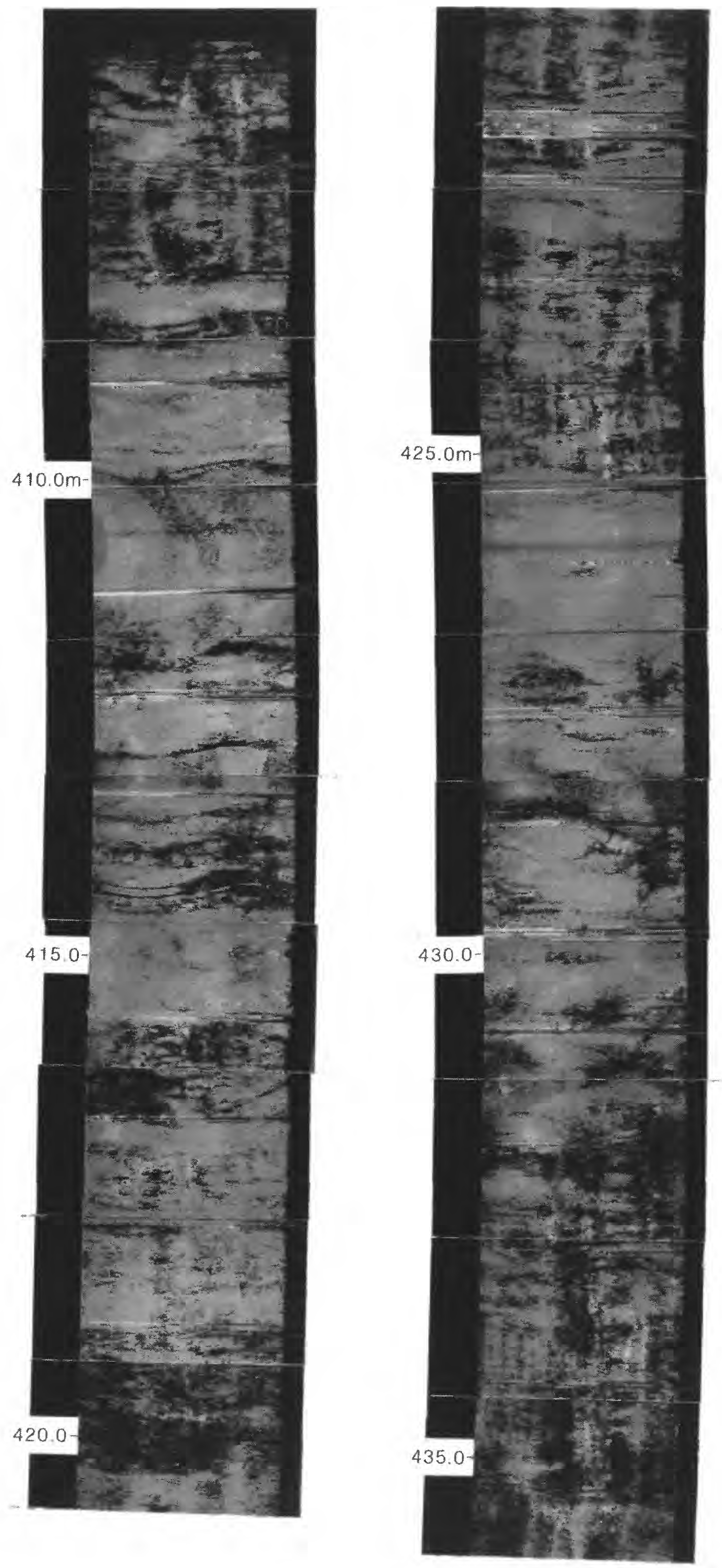

255.0m-
260.0-
265.0-
270.0m-
275.0-
280.0-

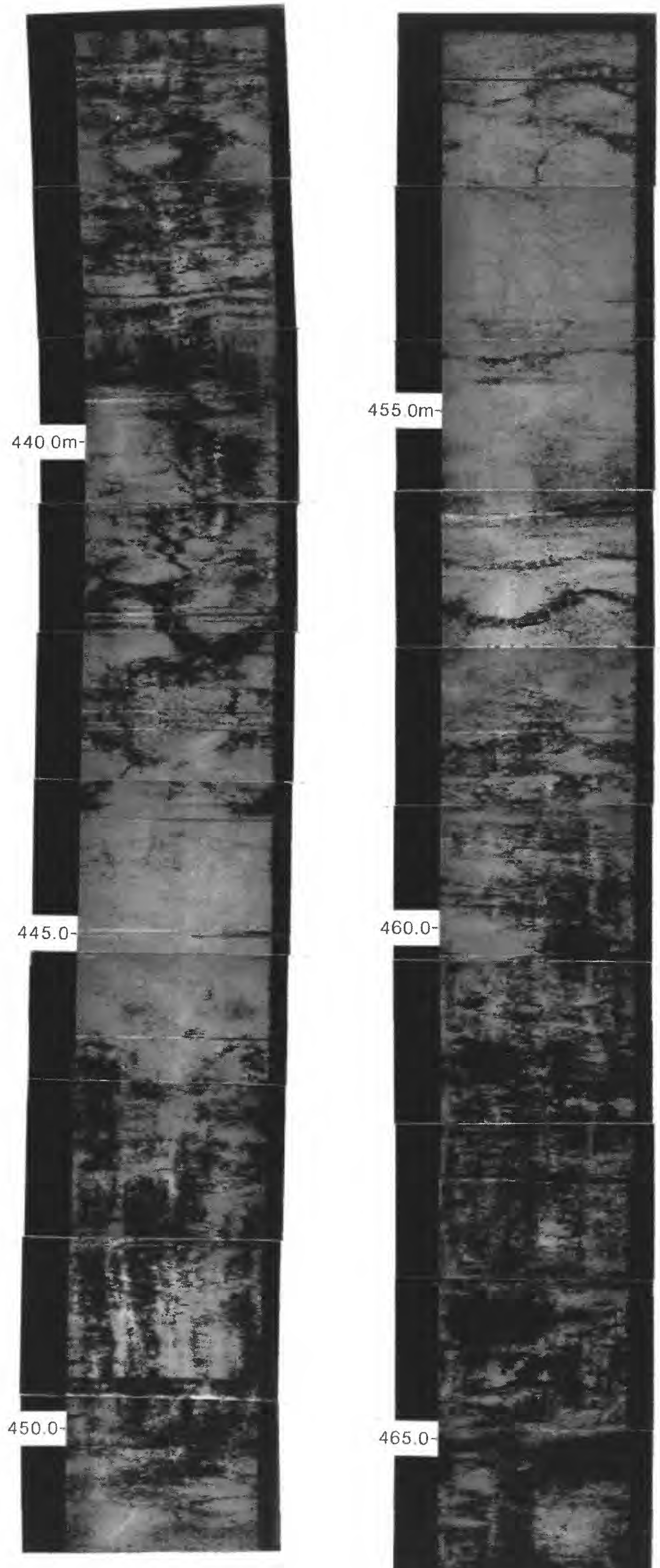

285.0m-
290.0-
295.0-
300.0m-
305.0-
310.0-

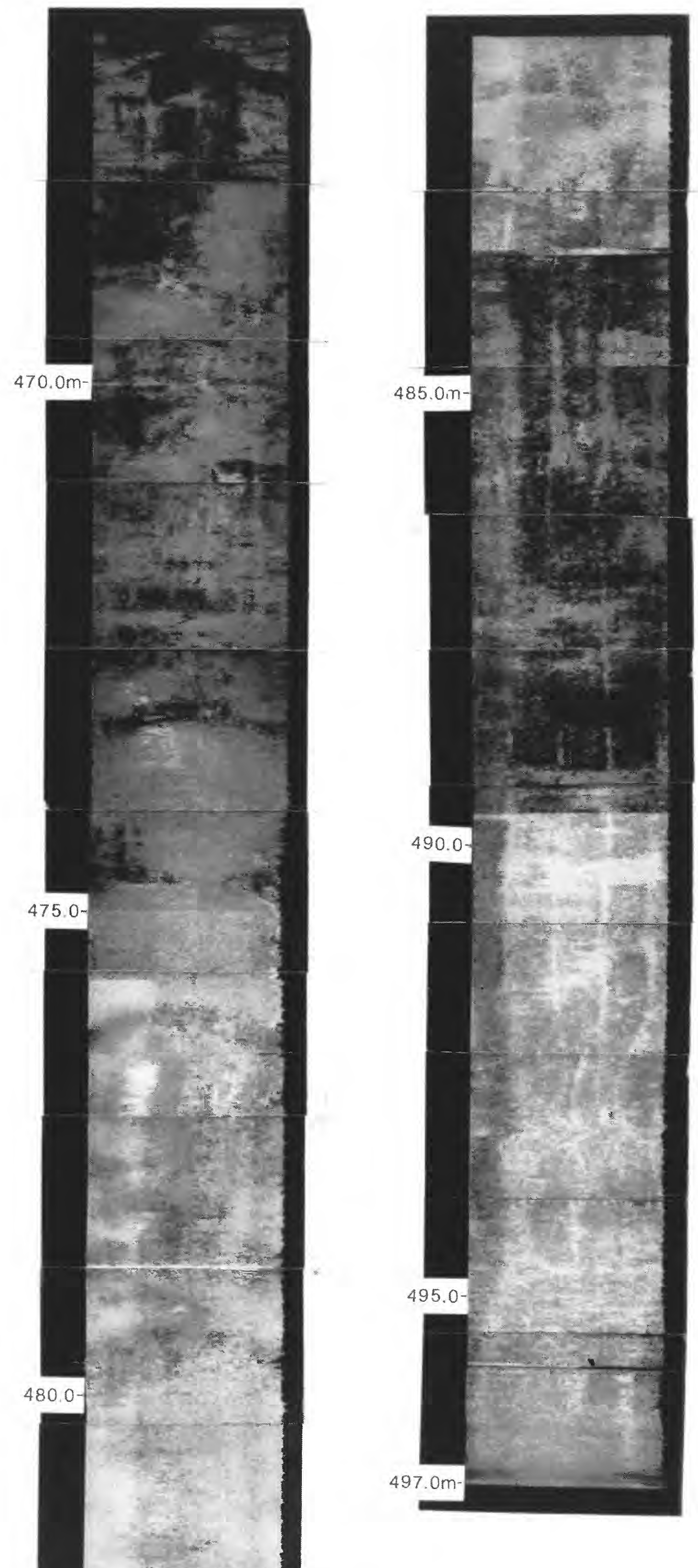

315.0m-
320.0-
325.0-
330.0m-
335.0-
340.0-


345.0m
350.0
355.0
360.0m
365.0
370.0


375.0m-
380.0-
385.0-
390.0-
395.0m-
400.0-
405.0-


410.0m-
415.0-
420.0-
425.0m-
430.0-
435.0-


440.0m-
445.0-
450.0-
455.0m-
460.0-
465.0-


470.0m-
475.0-
480.0-
485.0m-
490.0-
495.0-
497.0m-