GEOPHYSICAL REPORT

Key 5-70, 71-74, 75-78, 95-98, 115-118, 135-138

Mineral Claims, Skeena M.D.

104B - 1W, E

Lat. 56° 11'N; Long. 130° 15'W

Esso Resources Canada Limited

Submitted by

C. A. AIRD, P. Eng.

7483

October 10, 1979

TABLE OF CONTENTS

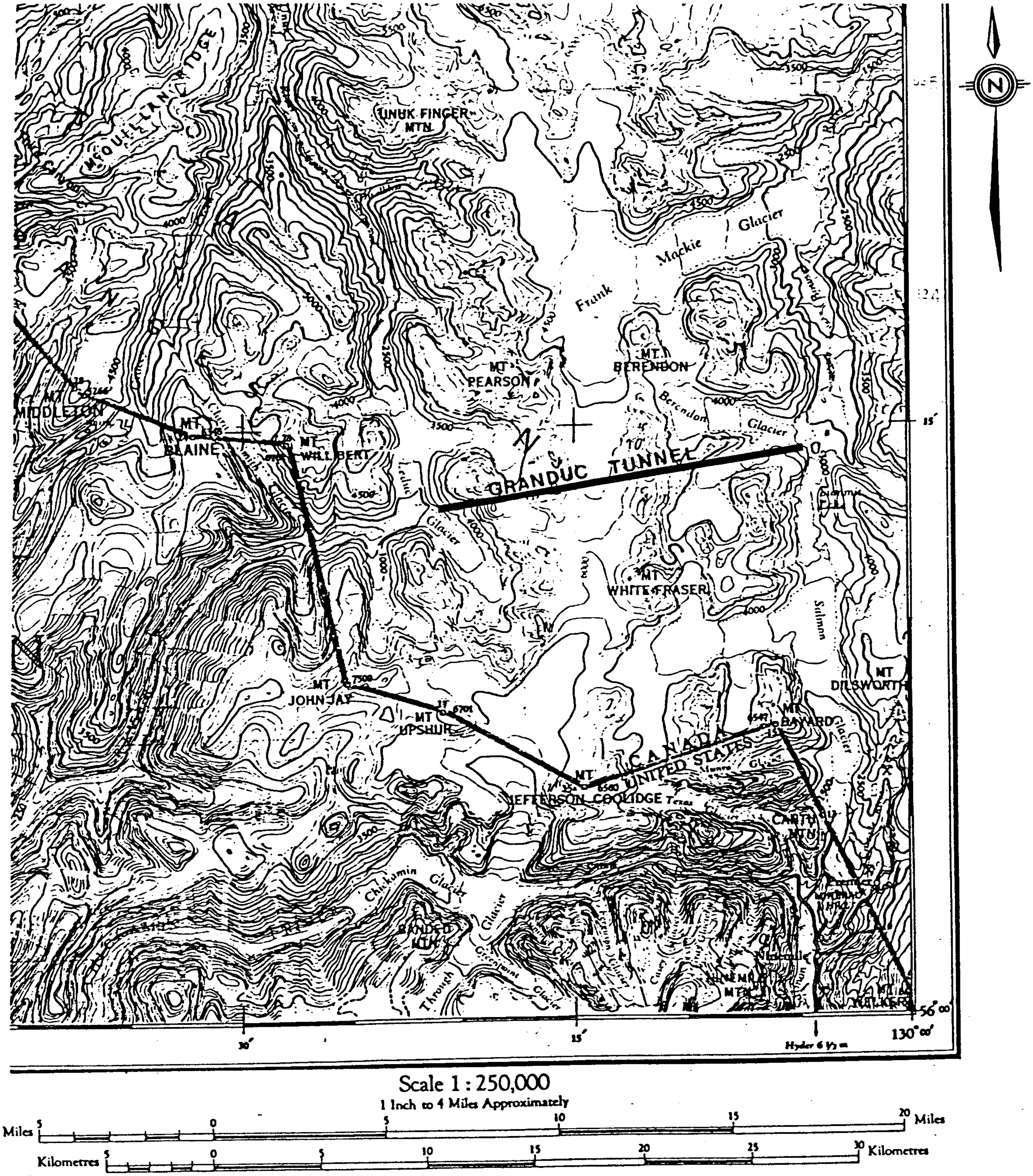
MAPS

SUMMARY

A geophysical research study was undertaken in the Granduc Mine Tunnel to determine the dielectric properties of the various rock types and to evaluate the use of ground probing radar as a geophysical survey tool underground.

Four men were required to conduct the survey which was conducted from a mobile unit operating on track within the tunnel.

Eight tests were carried out. The deepest penetration obtained from the radar signal was in the mine sediments. Results suggest that this equipment can be used to detect fracture zones, quartz veins and sulphide veins at distances up to 10 metres in the mine sediments.



ISKUT RIVER
SHEET 104 B

Page 2

INDEX MAP

Showing location of Granduc Mine Tunnel

LOCATION AND ACCESS

The Granduc Mine is located on the north limit of the South Leduc glacier. It is connected to the concentrator site at Tide Lake by a 17 kilometre (10.3 miles) tunnel. A gravelled road, 53 kilometres long (32 miles), connects Tide Lake with the town of Stewart, B.C., situated at the north east extremity of the Portland Canal.

Stewart may be reached by road from the south (Terrace, Hazelton) or from the north (Cassiar, Watson Lake). It is also serviced at least once a day (weather permitting) by Trans Provincial Airlines connecting with C.P. Air at Prince Rupert providing scheduled daily flights to Vancouver.

HISTORY

In 1951 and 1952, two prospectors, Einor Kvale and Tom McQuillan, staked the Granduc showings on behalf of Helicopter Exploration Company Limited. Granby Mining Company Limited optioned the property and with Helicopter Exploration formed a company named Granduc Mines Limited. The name is derived from a combination of Granby and Leduc.

A year or so later Newmont Mining Corporation acquired a half interest in Granduc Mines Limited and in 1964 Hecla Mining Company purchased an interest. In 1965 a reorganization took place and the property was leased to Granduc Operating Company, owned by Newmont, and to the American Smelting and Refining Company who shared the lease equally.

The mine was placed in production in 1970 and shipped its first load of concentrates to Japan in 1971 from a dock at Stewart.

The mine subsequently closed in 1977 during a period of depressed metal prices and the assets of Granduc Operating Company were purchased by Esso Resources Canada Limited in 1979. The mine itself was purchased from Granduc Mines Limited in return for a share of the net proceeds from production.

HISTORY (Cont'd)

Reopening of the mine is scheduled for mid 1980.

GEOPHYSICAL WORK

A geophysical research study was undertaken in the Granduc Mine tunnel to determine the dielectric properties of the various rock types and to evaluate the use of ground probing radar as a geophysical survey tool in underground mines.

Outside of the Geological Survey of Canada there is no known organization in Canada capable of performing radar surveys in mine openings. Consequently a contract was arranged with ENSCO INC. Earth Sciences and Systems Division of Springfield, Virginia to carry out the work.

The equipment procedures and results are described in ENSCO's report and the work was supervised in the field for Esso by Z. Doborzynski.

PROFESSIONAL PROVINCE OF C. A. AIRD BRITISH COLUMBIA ENGINEER

C.A. Aird, P. Eng.

CAA:O

October 10, 1979

COST STATEMENT

Survey Dates:	May 21, 1979 - May 27, 1979 inclusive (7 days)	
Contractor:	Ensco - two men and equipment @ $1698 per day	$ 11,886
Esso:	Geophysicist - @ $150 per day	1,050
	Labour - one man @ $60 per day	420
Transporation:	Helicopter 7 hours @ $300 incl. fuel	2,100
Room & Board:	28 man-days @ $50 per day	1,400
	Total	$ 16,856

I hereby certify that the above statement is correct:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
C. A. AIRD

C.A. Aird, P.Eng.

CERTIFICATION

I, Zbigniew B. Doborzynski of 6167 Starfield Crescent, Mississauga, Ontario hereby certify that:

1. I am a Graduate of McGill University with a B.Eng in Applied Geophysics and Mining Engineering and a M.Sc in Applied Geophysics.

2. Since 1974, I have been employed by Imperial Oil Ltd. as a Minerals Geophysicist in Nova Scotia, Quebec, Ontario British Columbia and N.W.T.

3. I am a member of the Association of Professional Engineers of Ontario.

4. I hold no direct or indirect interest in the mining properties reported herein nor do I expect to receive any.

Z. Doborzynski

Z. B. Doborzynski

ENSCO, INC. 5408A Port Royal Road ■ Springfield, Virginia 22151 ■ (703) 321-9000
EARTH SCIENCES AND SYSTEMS DIVISION

29 August 1979

TO WHOM IT MAY CONCERN:

I, James C. Fowler, 9432 Wallingford Drive, Burke, Virginia, certify and declare that I am a graduate of New Mexico State University with a B.S. degree in Electrical Engineering in 1965, and the University of Missouri-Rolla with a M.S. and Ph.D. in Electrical Engineering in 1967 and 1968, respectively.

My experience includes six years as a research scientist and research group leader with the Exploration Research Division of CONOCO, Inc. In this position I was responsible for the development of exploration methods for oil and minerals. I have spent three years with ENSCO, Inc. and my position now is that of Chief Engineer of the Earth Sciences and Systems Division. In this position I am responsible for the development of techniques to remotely sense the physical properties of rocks.

I have no interest in ESSO Minerals of Canada, nor do I expect to receive any interest in the company or any of their properties.

My report was based upon the results of field tests at the Granduc Mine which I managed, and upon published and unpublished data.

James C. Fowler

James C. Fowler, Ph.D.
Chief Engineer

JCF/gs

7483

ENSCO Contract No. 1326

July 31, 1979

RADAR TESTS AT GRANDUC MINE
BRITISH COLUMBIA

FINAL REPORT

Prepared for:

ESSO MINERALS CANADA
Box 4029 Terminal "A"
Toronto, Canada M5W 1K3

Prepared by:

ENSCO, INC.
Earth Sciences and Systems Division
5408A Port Royal Road
Springfield, VA 22151

7483

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF TABLES AND FIGURES (Cont'd.)

RADAR TESTS AT GRANDUC MINE
BRITISH COLUMBIA

1. INTRODUCTION AND SUMMARY

A series of ground probing radar tests were conducted in the Granduc Mine during the week of May 21, 1979. The purpose of the tests was to evaluate the use of ground probing radar to measure the electrical properties of the rock at various locations in the mine. These tests were designed to measure the dielectric constant of the rock and to determine the fracturing in the rock. Additional tests were designed to specifically measure the effects of discontinuities such as quartz veins in the radar signal and to determine maximum penetration depths for the radar.

The work was conducted at various locations in the Tide Tunnel of the mine. Table I shows the calculated dielectric constant at each of the test locations. A measure of the fracturing was also determined at each of the test locations.

The rocks at each test site were easy to evaluate with the exception of the diabase at Site 6. The inability of the radar to see reflections from within the diabase made it impossible to determine whether the energy was penetrating the rock. However, at locations in the mine sediments the radar was able to detect features such as quartz veins and fractures which are often associated with mineralization. The location of the quartz vein was mapped to a distance of 6.5 meters while major fractures were mapped at distances of 4 meters.

TABLE I. SUMMARY OF ROCK PARAMETERS

SITE	LOCATION	DIELECTRIC CONSTANT	ROCK TYPE	JOINTS
1	2000'	8.7	Granodiorite	Highly Jointed
2	54000'	10.0	Andesite	Highly Jointed
3	54000'	5.8	Sediments	Highly Jointed
4	15000'	6.2	Siltstone	Medium
5	15000'	6.5	Granodiorite	Medium
6	40000'	6.3	Diabase	?
7	35000'	7.3	Pillow Lava	Fewest Joints
8	30000'	14.1	Greenschist	Medium

This series of tests showed that the radar can obtain a measurement of the electrical properties of rocks in situ. The system can be used to map discontinuities throughout the mine to depths in excess of 10 meters. Thus, even with this somewhat limited range, it is possible to use the radar for many possible safety and production related tasks.

2. DESCRIPTION OF FIELD TESTS

2.1 WHAT RADAR MEASURES

The radar used in these tests was a special geophysical radar unit designed to map reflections from within rock masses. Figure 1 shows a block diagram of the system. The system consists of a transmitter, receiver, radar controller, graphic display, and a tape recorder. The transmitter and receiver include the antennas and their associated electronics. The antennas are designed to be moved either independently or in unison along the surface of the geologic target. The controller provides the timing signals for the transmitter and receiver, then amplifies and filters the received signal before recording. The tape recorder is a standard multichannel recorder which provides a permanent record for the data. The graphic recorder is a specially built facsimile recorder to provide real-time analysis of the radar returns. The system is designed to be operated in the field from two standard automobile batteries.

The radar signal propagates through the earth material and is reflected from electrical discontinuities in the earth. The determining factor for the transmission of the radar signal is the dielectric constant of the rock. The dielectric

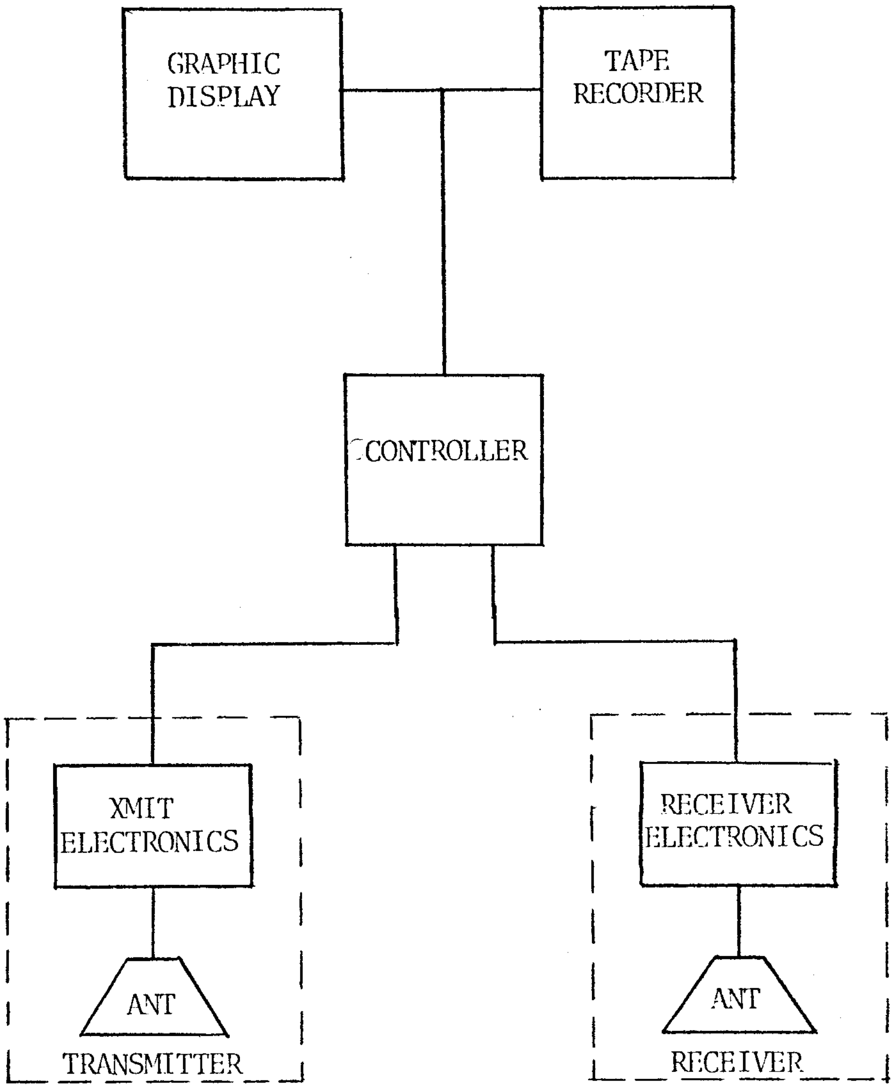


Figure 1. Diagram of Radar

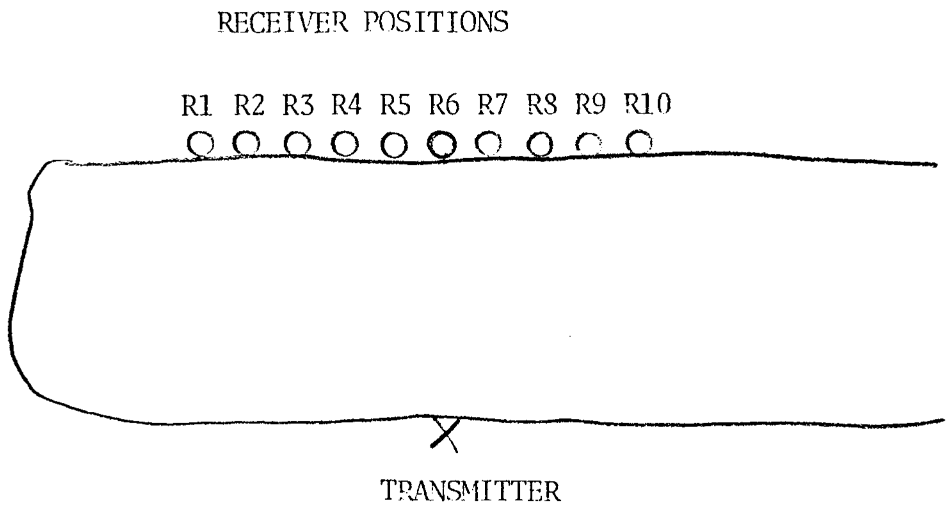
constant is determined by both the type of rock material and the amount of water in the rock. When either one or both of these components change, the dielectric constant changes. Any change in dielectric constant will cause a portion of any incident radar energy to be reflected.

In order to evaluate and compare rock properties in many different areas of the mine, a series of standard tests were used. The tests were of three different types, each designed to provide information as to the electrical properties of the rock and the types of discontinuities and fractures in the rock.

The first test is the transillumination test. In this configuration the transmitter is on one side of the geologic feature while the receiver is on the other. Figure 2 shows this configuration. The receiver is moved along the wall to enable the unique identification of the signal. A typical series of received signals are shown in the lower portion of Figure 2. Note that the received signal occurs earlier in time as the receiver moves to a point directly opposite the transmitter. If the transmit and receive locations are surveyed, it is then possible to obtain a measurement of the velocity of propagation of the radar signal. This is related to the relative dielectric constant by

$$k = \left(\frac{c}{v}\right)^2$$

where k = relative dielectric constant of the material
v = velocity of propagation in the material
c = speed of light in air (.3 m/nsec)
1 nsec = $1\text{x}10^{-9}$ seconds



TYPICAL RECEIVED DATA

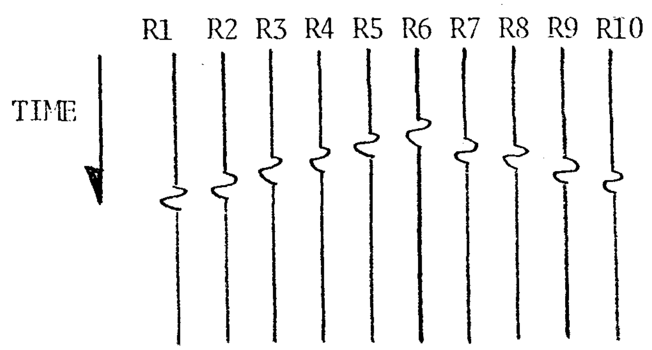


Figure 2. Transillumination Test

7483

This test also provides information on the maximum possible distance signals can propagate the rock. Maximum reflection ranges are generally about half of the maximum penetration distance.

The second type of test is also designed to provide information on the velocity of propagation and the maximum reflection ranges. This test is called the "walkaway" and is shown in Figure 3. It is designed to be used in areas where it is impossible to do a transillumination test. In this configuration both the transmitter and receiver are on the same side of the pillar. The transmitter is held fixed and the receiver is moved away. If there is a reflector in the rock then the arrival time of the signal changes as the receiver moves. The lower portion of Figure 3 shows the type of reflection signal which will be seen in this test.

Measuring the arrival time of the reflection at two different antenna separations (offsets) allows the calculation of the velocity by

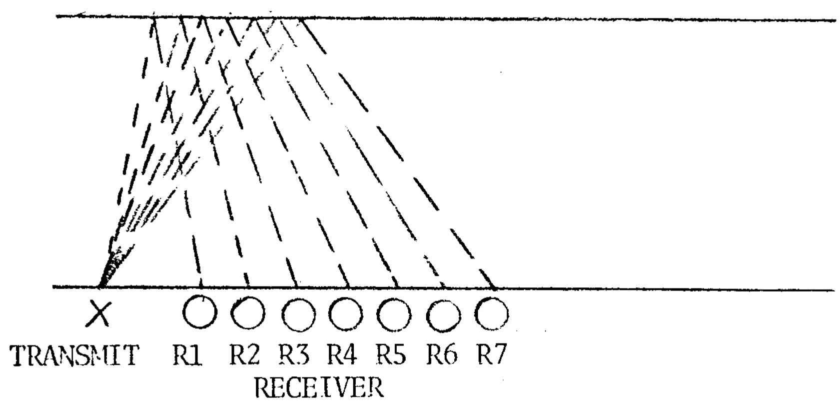
$$v = \frac{\sqrt{O_2^2 - O_1^2}}{\sqrt{t_2^2 - t_1^2}}$$

where O_2, O_1 are the two offsets in meters

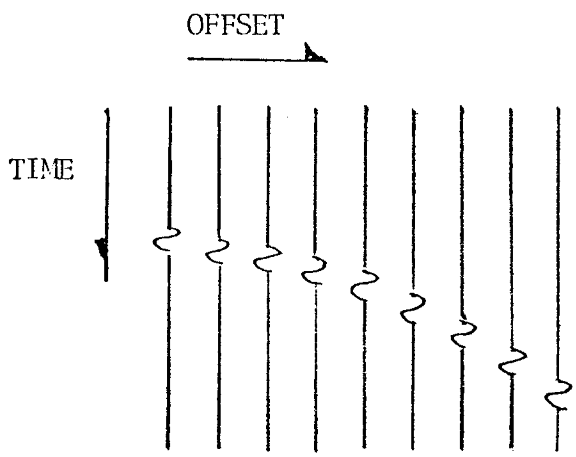
t_2, t_1 are the arrival times at each offset in nseconds

and

v is the velocity in m/nsec



TRANSMIT/RECEIVE GEOMETRY



TYPICAL RETURN

Figure 3. CDP Walkaway Test Layout

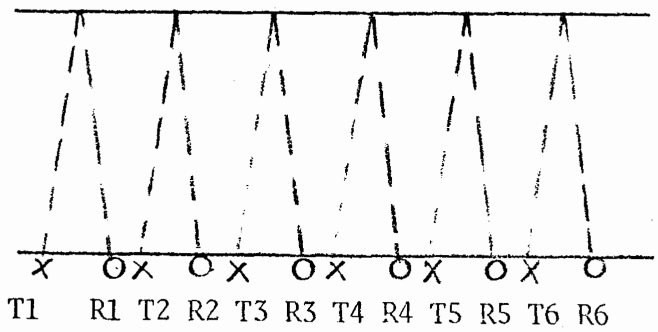
This type of measurement depends upon a large reflector parallel to the wall on which the antennas are located. This is not always possible; however, in most cases reasonable velocity estimates can be made from moderate reflectors. The "walkaway" test also allows the identification of spurious returns since any arrival with abnormally high velocity can be easily located and ignored in further interpretations.

The final test configuration is the constant offset traverse (shown in Figure 4). In this configuration both the transmitter and receiver are moved along the wall. The two units are kept at a constant separation. This is the type of survey used to map the discontinuities in the rock walls over extended lengths of traverse.

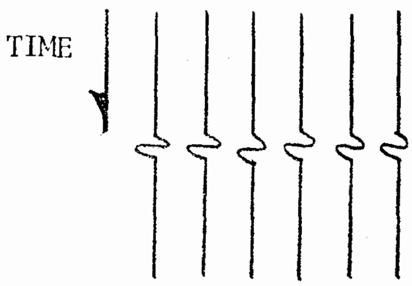
2.2 FIELD TESTS

All three of the types of tests were used during the Granduc work. We also used two different radar systems. The first radar operated with a center frequency of 350 MHz while the second had a 120 MHz center frequency. The high frequency unit was used to map to shallow depths with high resolution while the lower frequency unit penetrates further but has lower resolution.

The field tests at Granduc were conducted at several sites in the tide tunnel. The first test site was located at the tail track and conveyor drift about 2000 feet into the tunnel. Figure 5 shows the area of the test site. Transillumination tests were conducted along the pillar to measure the velocity of propagation. Figure 6 shows the results of this test. Note that the signal is relatively strong and the total transit time for the pillar is 65 nsec. The thickness of the pillar is 6.6 meters; this corresponds to a velocity of .102 m/nsec. These measurements imply a dielectric constant of 8.7 for this rock. This is a nominal value for consolidated rock.



CONSTANT OFFSET GEOMETRY



TYPICAL RETURN

Figure 4. Constant Offset Traverse

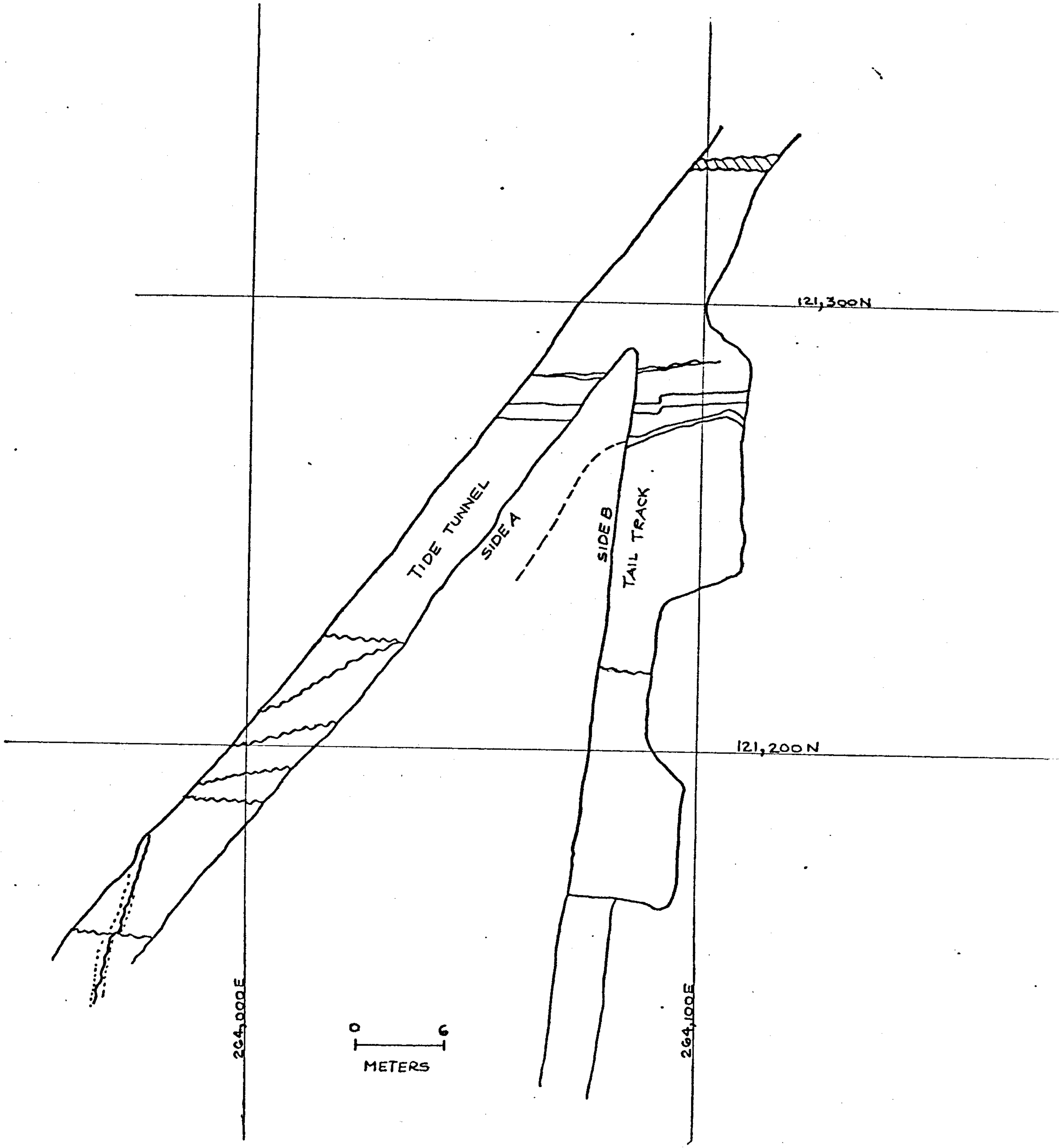


Figure 5. Granduc Test Site #1

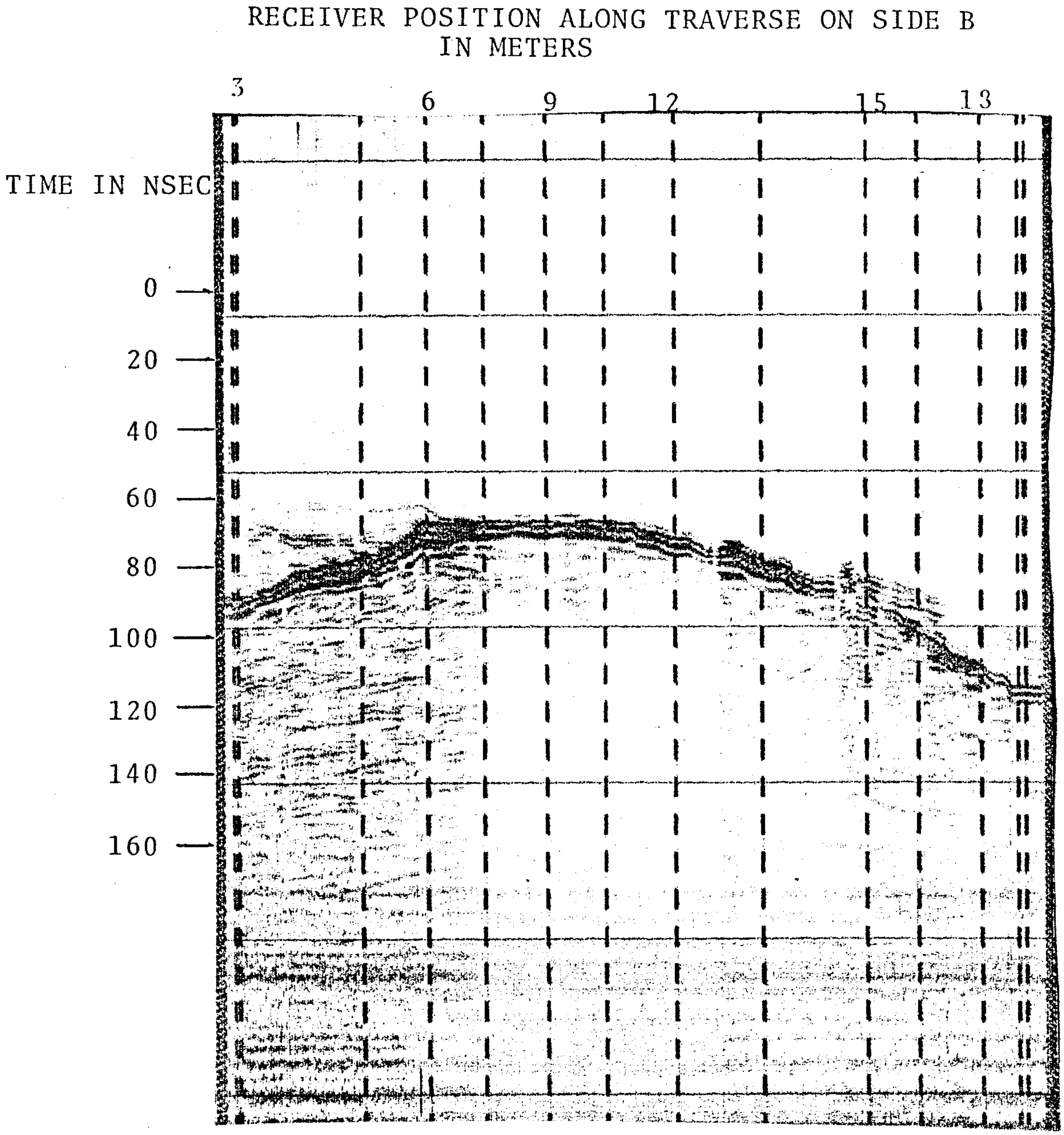


Figure 6. 350 MHz Transillumination Site 1 Transmitter Located 12 Meters In On Side A

Before discussing the rest of the tests, we must discuss some of the artifacts of the system which appear on the radar displays. The uniform vertical dashed lines which appear are range marks inserted by the operator to correspond to known positions along the traverse. In all of the displays the radar signal appears as a series of dark lines. This is because the facsimile display burns the paper according to the amplitude of the signal. Thus low signal levels appear as white areas while high signal levels appear as dark areas. Finally, the radar controller has a time gain amplifier which amplifies the end of the recorded trace more than the beginning. This makes the random noise and system noise greater at the end of the trace. This can be seen in Figure 6 as a series of horizontal lines in the portion of the radar returns below 160 nsec. The rest of the figures will have similar noises.

Figures 7 and 8 show the results of four different "walkaway" tests. In each of these tests several reflectors are easily identified. The reflector which arrives at the latest time is the back side of the pillar. The earlier reflections are probably from the various discontinuities which cross the pillar in the first few meters. The final test along this part of the pillar was a constant offset traverse along Side A. Figure 9 shows the results of this traverse. Note that the back side of the pillar is seen as the return which slopes away as the antennas are moved along the traverse. The reflection can be tracked almost throughout the length of the traverse. The signal becomes extremely weak at the 16 meter position ($\approx$150 nsec). At this point the pillar is a little over 8 meters thick. A second major reflector is seen at the 70 nsec level between the 9 meter and 18 meter positions. This reflector tends to run parallel to Side A about 3.5 meters into the pillar. It is probably associated with the third joint system shown on the tail track side of the pillar. This joint enters the pillar at the marked location then probably curves to become almost parallel to Side A (see the dotted line in Figure 5).

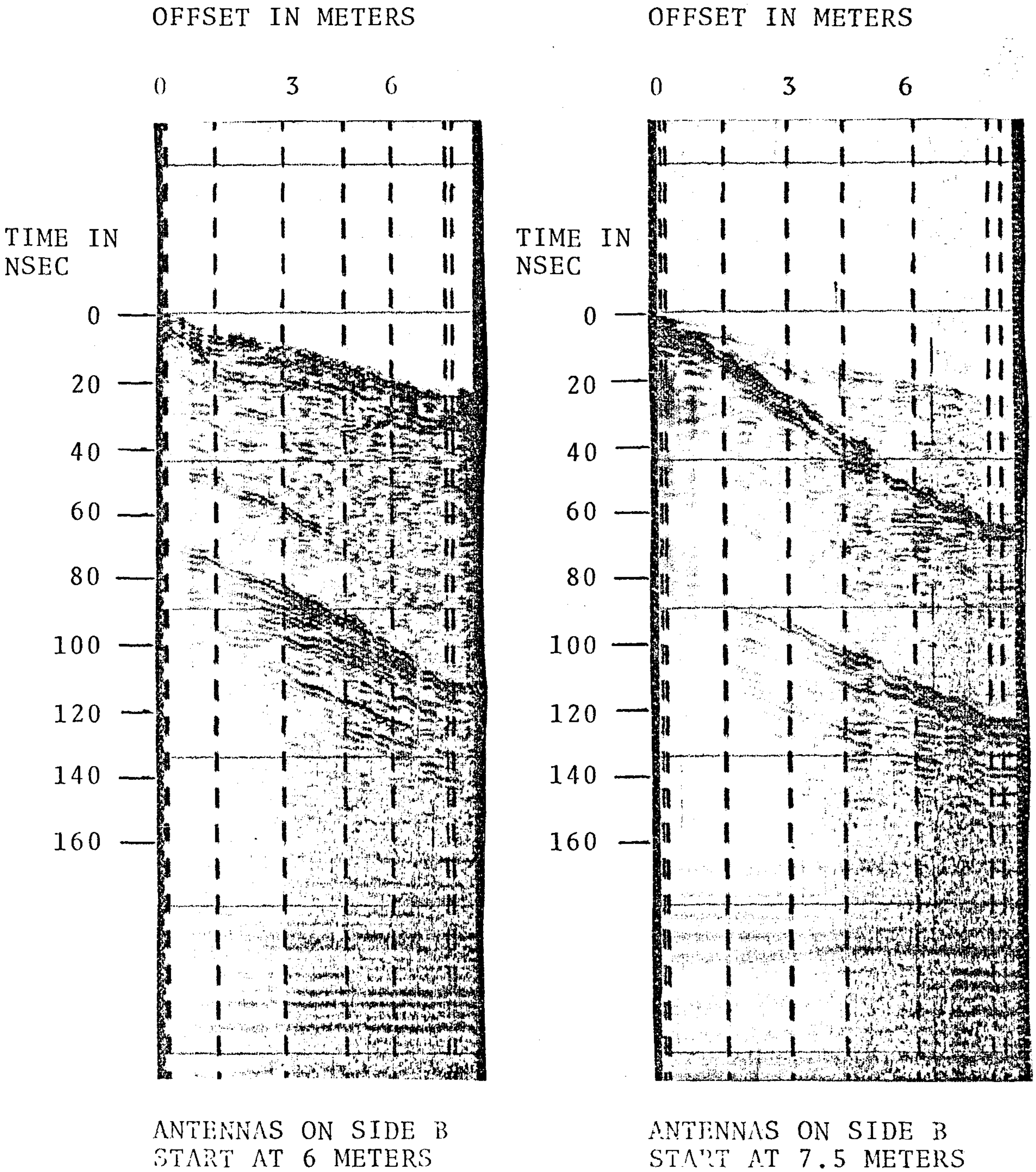


Figure 7. 350 MHz CDP Walkaway Site 1

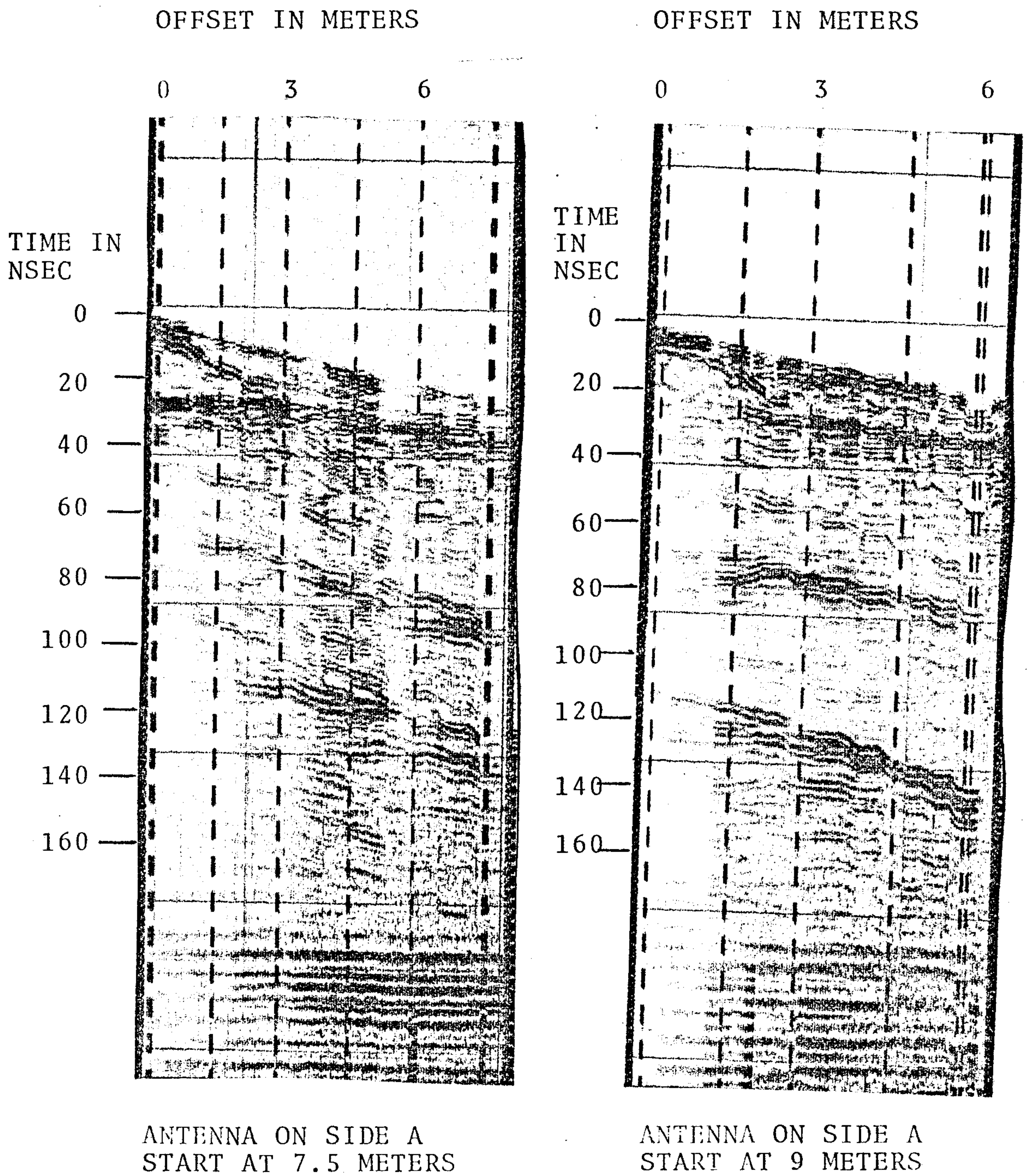


Figure 8. 350 MHz CDP Walkaway Site 1

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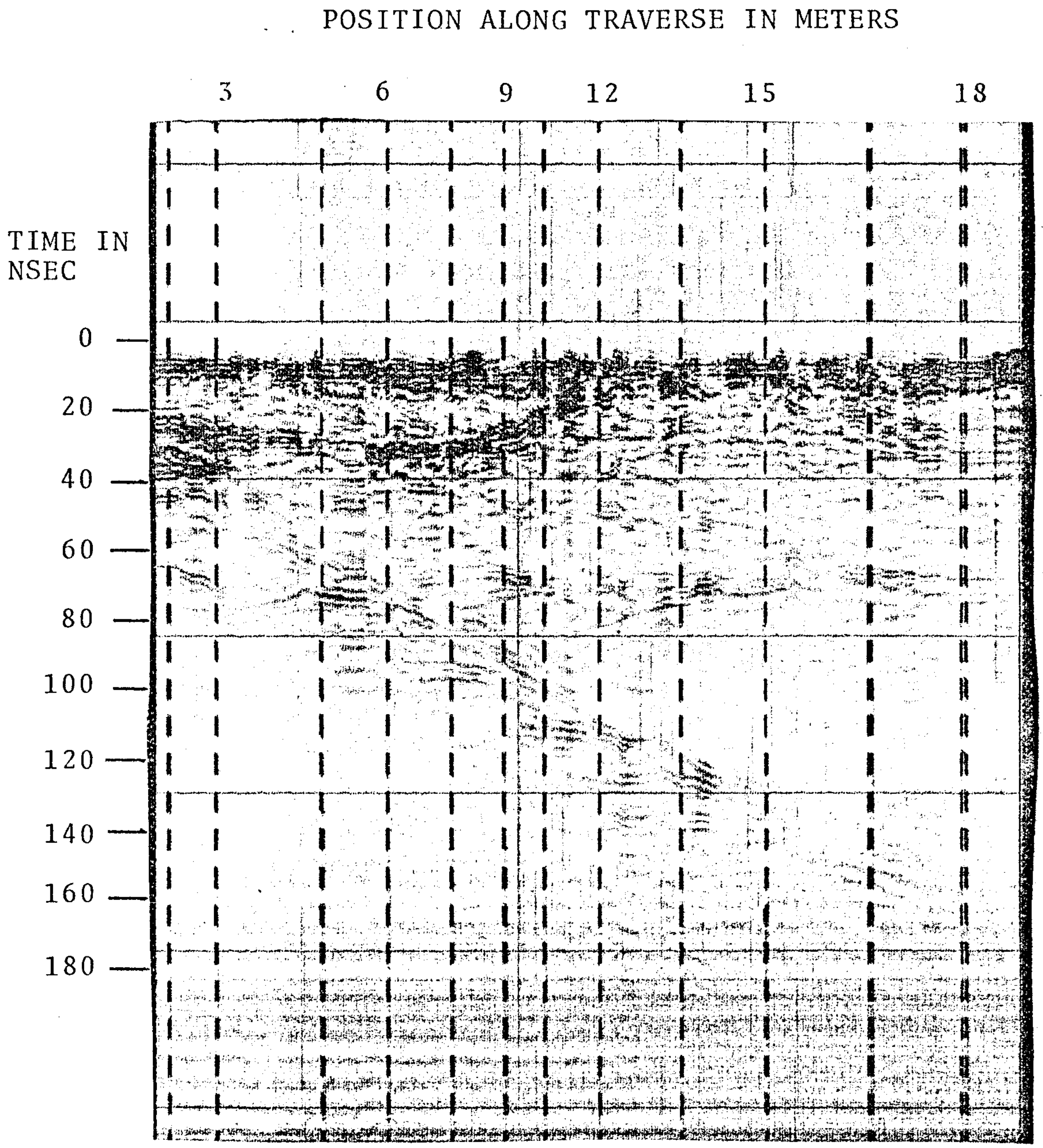


Figure 9. 350 MHz Traverse Side A Site 1
Offset = 1.5 Meters

Additional tests were conducted with the lower frequency antennas in the thicker portion of the pillar. Figure 10 shows the transillumination test at a position 31.5 meters from the start of the pillar. The thickness of the pillar at this point is about 17 meters. The signal through the pillar is only about 10 times that of the system noise, therefore it is impossible to see reflections through the total pillar at this location. In order to evaluate the ability to see reflections in the pillar, two tests were conducted. Figure 11 shows a walkaway conducted on Side B 30 meters from the end of the pillar. Two reflectors can be seen starting at 70 nsec and 110 nsec, respectively. However, the back side of the pillar cannot be seen. Figure 12 shows a traverse run along Side B. The major reflectors at the start of the traverse are about 4.5 meters into the wall and run roughly parallel to the opposite side. Several other returns are seen at various locations, but no major reflection zones are visible.

The results of the tests at the first site were very encouraging. The rock proved to be very competent and had few major reflection zones. The major reflectors corresponded to a mapped joint system and the back side of the pillar. The dielectric constant of the rock was relatively low which indicates that the rock is relatively dry and does not have extensive gouge zones. The geology report confirmed this conclusion in that the general rock type in this area is a granodiorite.

The second test site was located at the other end of the Tide Tunnel near the engineering offices at the 54,000 feet position. A series of pillar tests were conducted at this site. Figure 13 shows the results of the first test. The pillar is thicker than that at the first site, however we do not have an exact survey of the site to enable an accurate measurement of velocity. The signal level is comparable to that at the first site so it should be possible to see reflections through the pillar. Figure 14 shows the walkaway test. Note

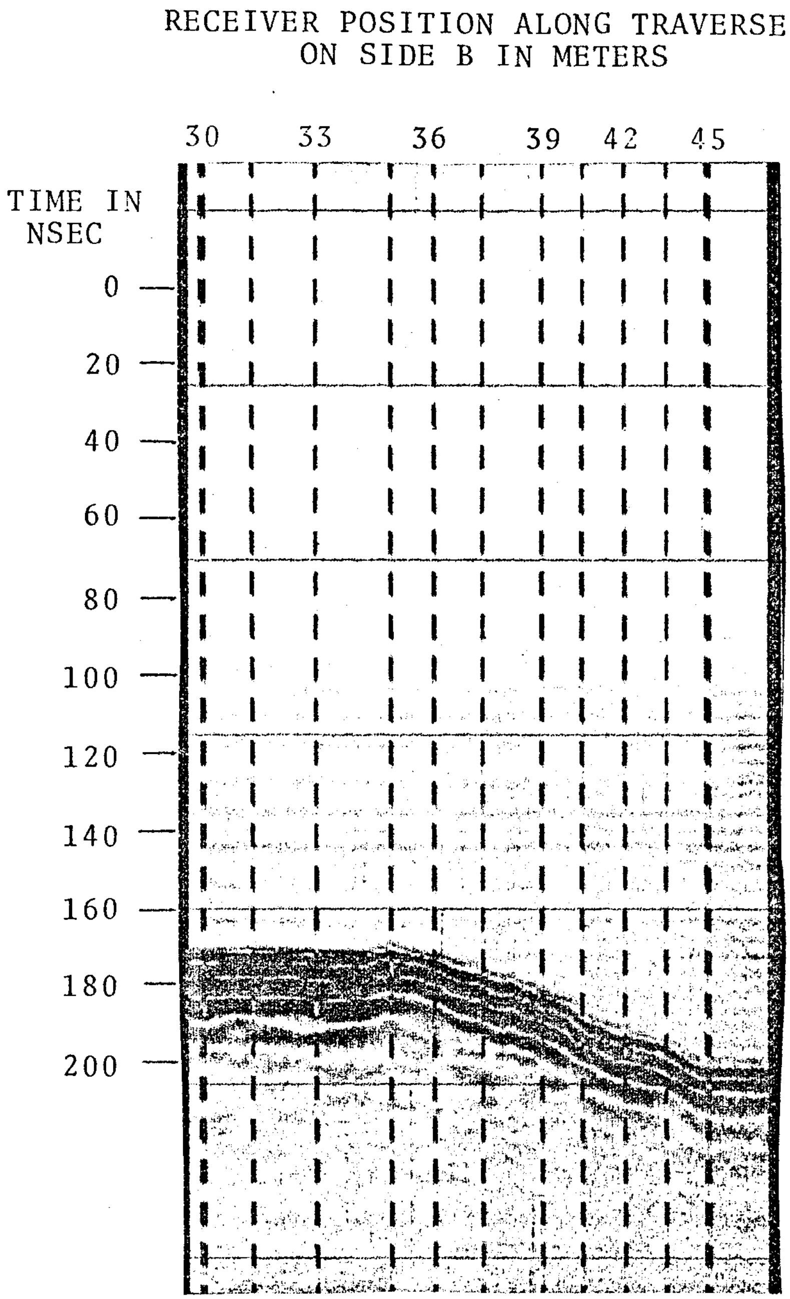


Figure 10. 120 MHz Transillumination Site 1 Transmitter Located 31.5 Meters Along Side A

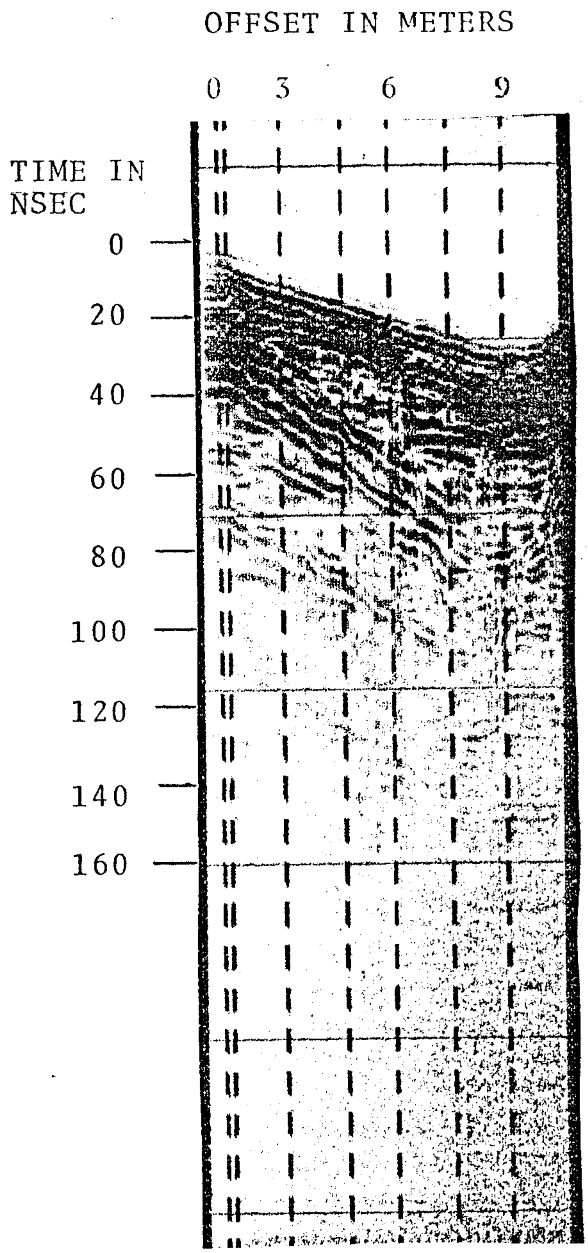


Figure 11. 120 MHz CDP Walkaway Site 1
Transmitter Located 30 Meters
Along Side B

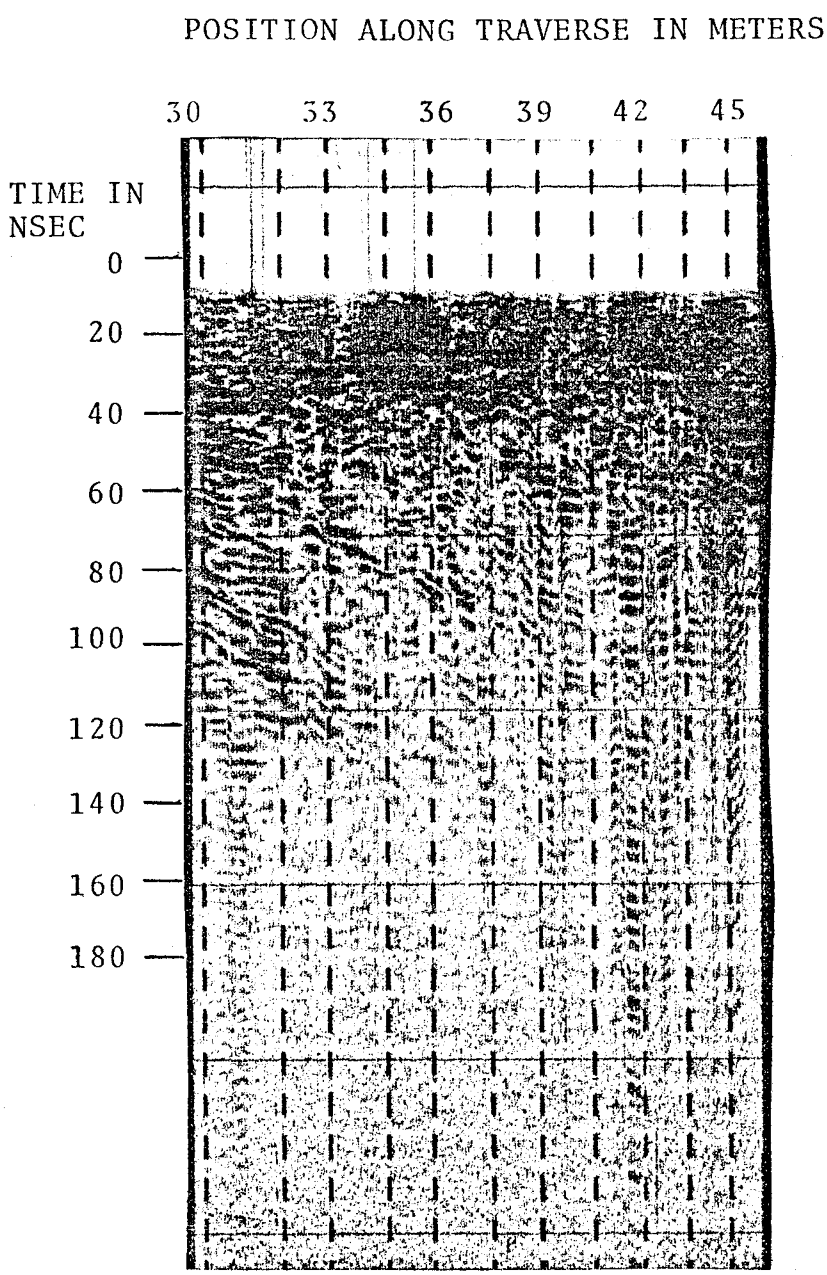


Figure 12. 120 MHz Traverse Side B Site 1
Offset = 3 Meters

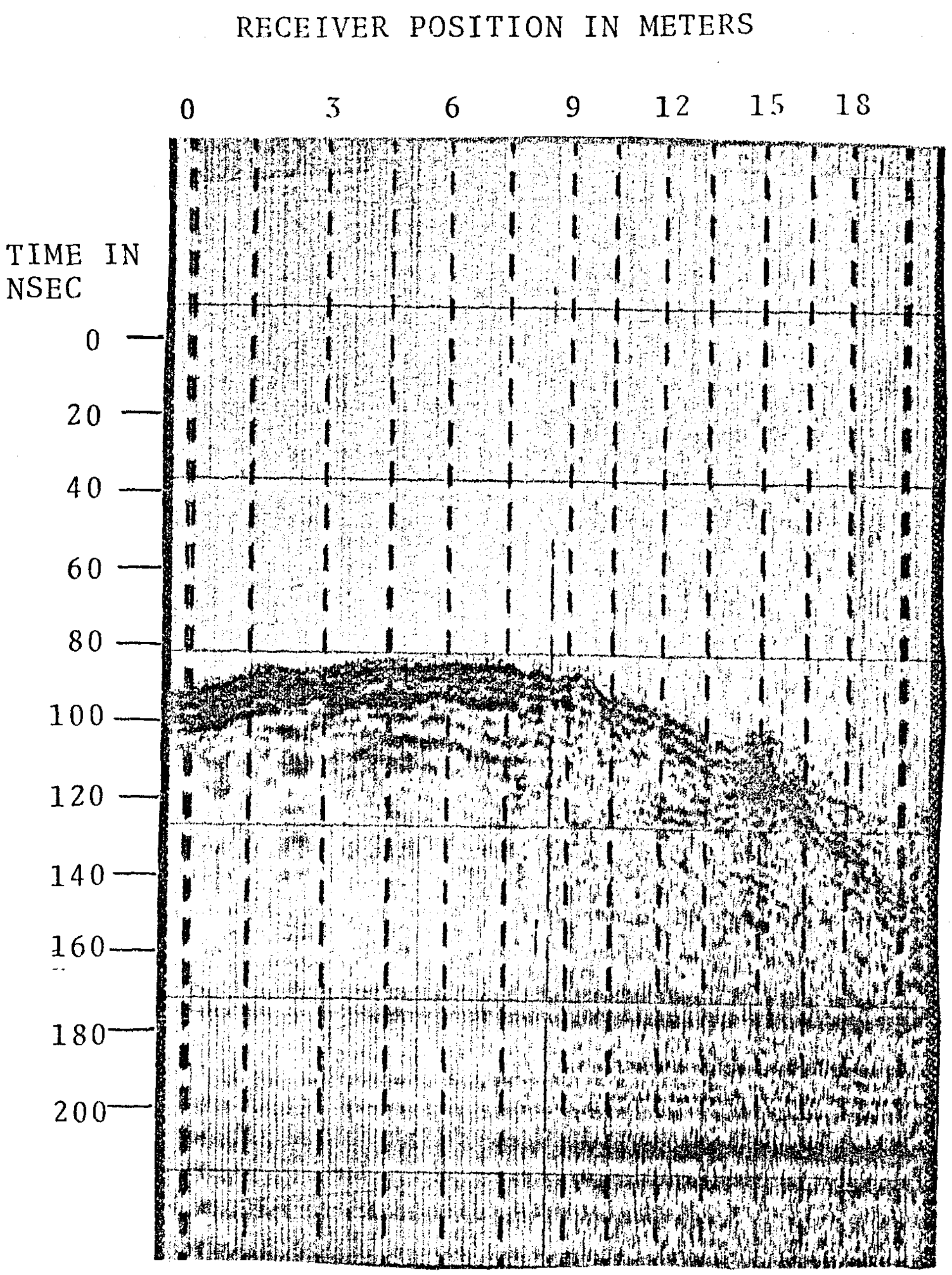
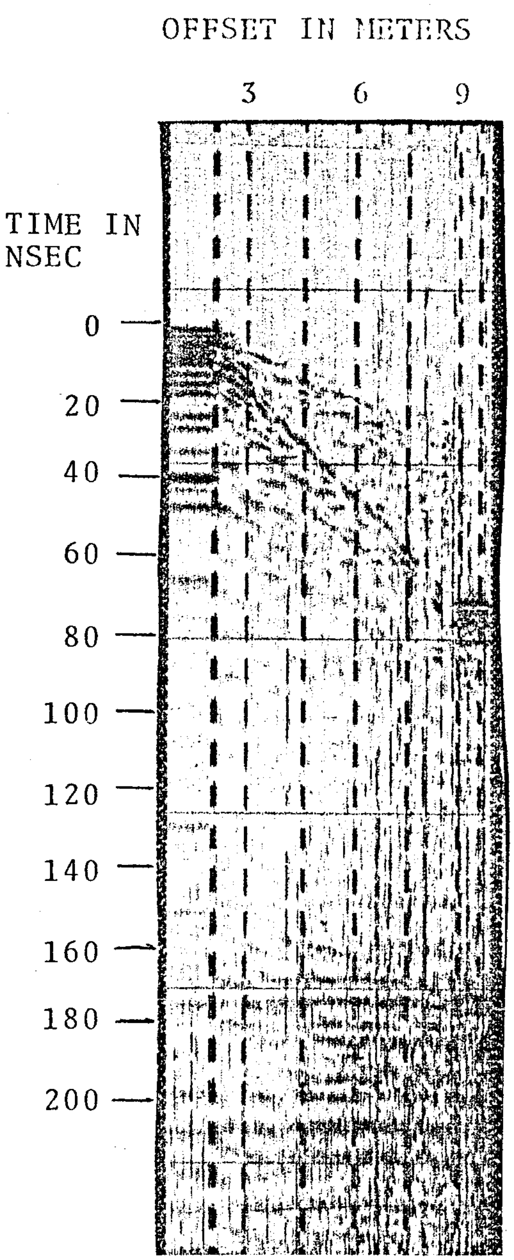
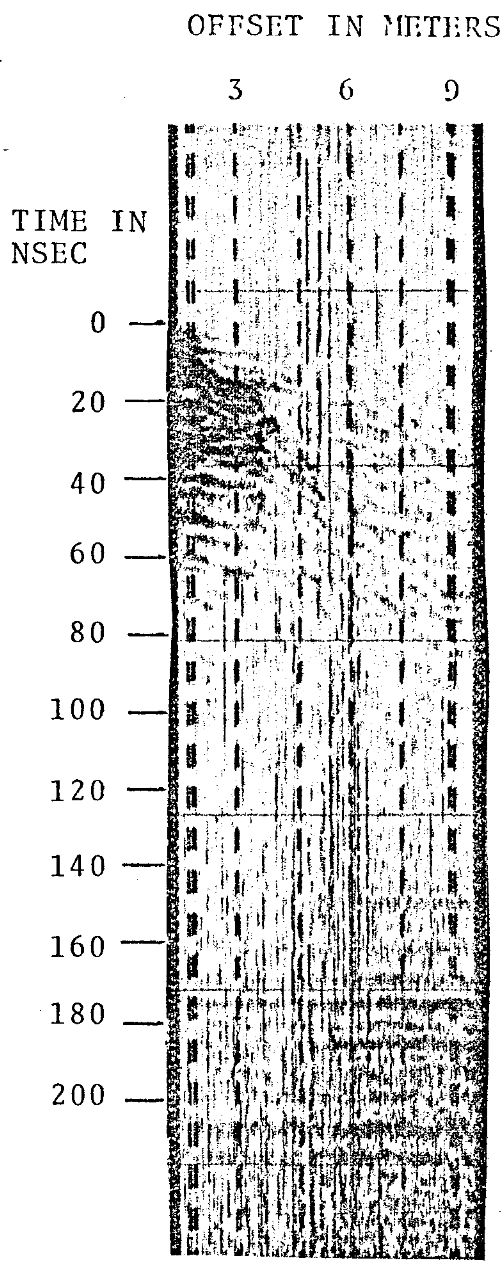


Figure 13. 350 MHz Transillumination Through Pillar Site 2



TRANSMITTER LOCATED
3 METERS FROM START



TRANSMITTER LOCATED
9 METERS FROM START

Figure 14. 350 MHz CDP Walkaway Site 2

that a reflection is visible on the first test about 160 nsec down the record. The reflection in the second test is not seen because of the noise in the record.

Figure 15 shows a traverse along the pillar. The back side of the pillar is visible in the 160 nsec to 180 nsec range. The 350 MHz radar has too much attenuation to accurately map through the distances involved. Therefore, the same series of tests were conducted with the 120 MHz antennas. Figures 16, 17, and 18 show the results of these tests. Using the reflection located at 160 nsec on the first walkaway, it is possible to calculate a velocity of .0949 meter/nsec. This then can be used on the data in Figure 18 to calculate a thickness of 8.6 meters for the pillar at the 9 meter mark.

In addition to the ability to map the back side of the pillar, the radar shows how the fractures in the rocks are distributed through the pillar. At the end of the pillar the reflections are distributed throughout the trace while as the radar moves 18 meters to 20 meters along the pillar the reflections in the center of the pillar decrease. This indicates that the fracturing and water saturation of these fractures occurs near the edges of the pillars and that as you got further into the pillar the rocks show fewer water saturated fractures. The principal type of rock in this area is an andesite which has a measured delectric constant of 10. This is slightly higher than the granodiorite at the first site but not significantly different.

The third test site was located a few hundred meters from the second site at the end of the tunnel. This site was near the mine sediments. There were no pillars at this site to use so the only velocity data was obtained from the walkaway tests. Figure 19 shows the 120 MHz walkaway tests at this site. Using the reflection arrival at 80 nsec on the second test, it is possible to calculate a velocity of propagation of .125 m/nsec. Figure 20 shows the traverse along the wall away from the corner.

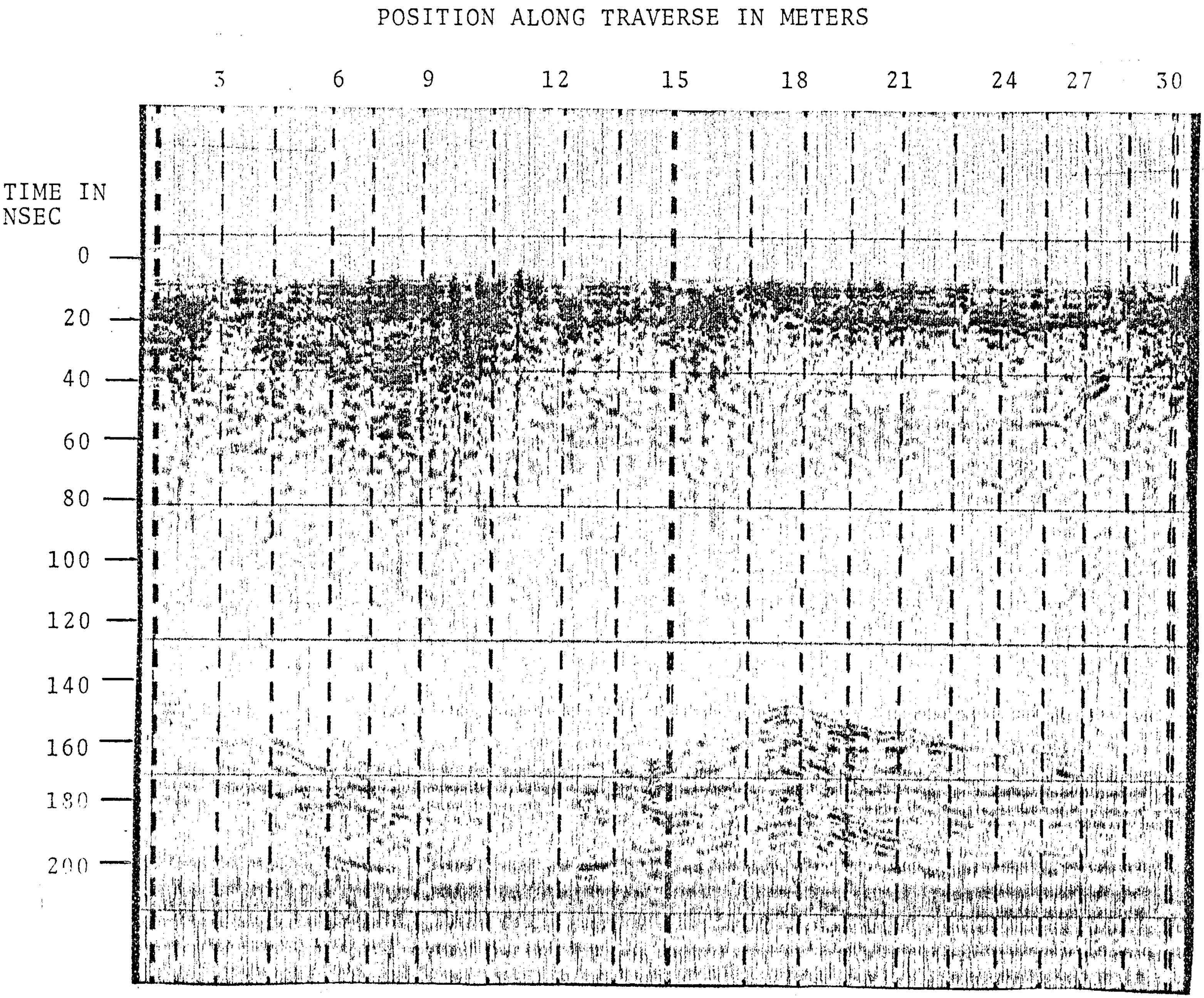


Figure 15. 350 MHz Traverse Along Pillar Site 2
Offset = 1.5 Meters

7483

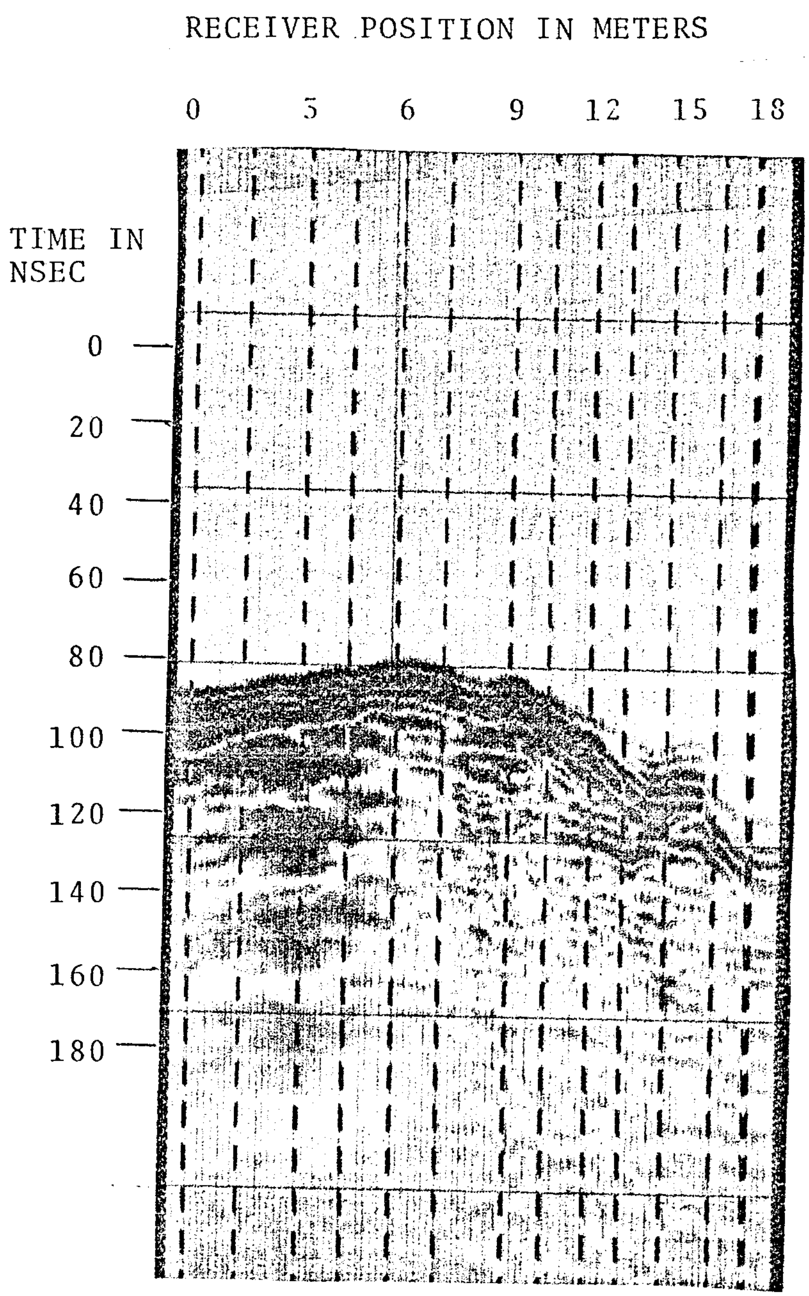


Figure 16. 120 MHz Transillumination Through Pillar Site 2

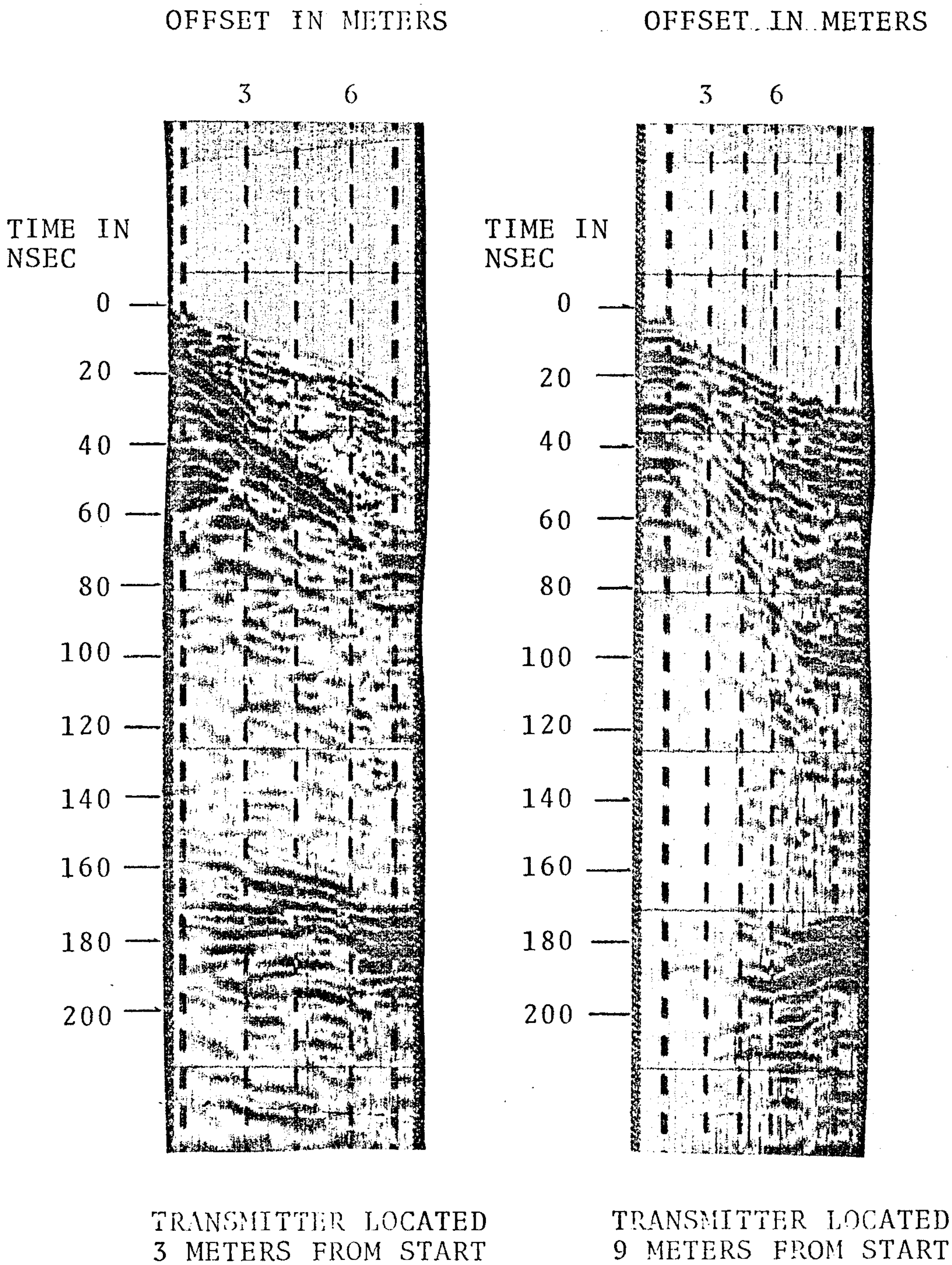


Figure 17. 120 MHz CDP Walkaway Site 2

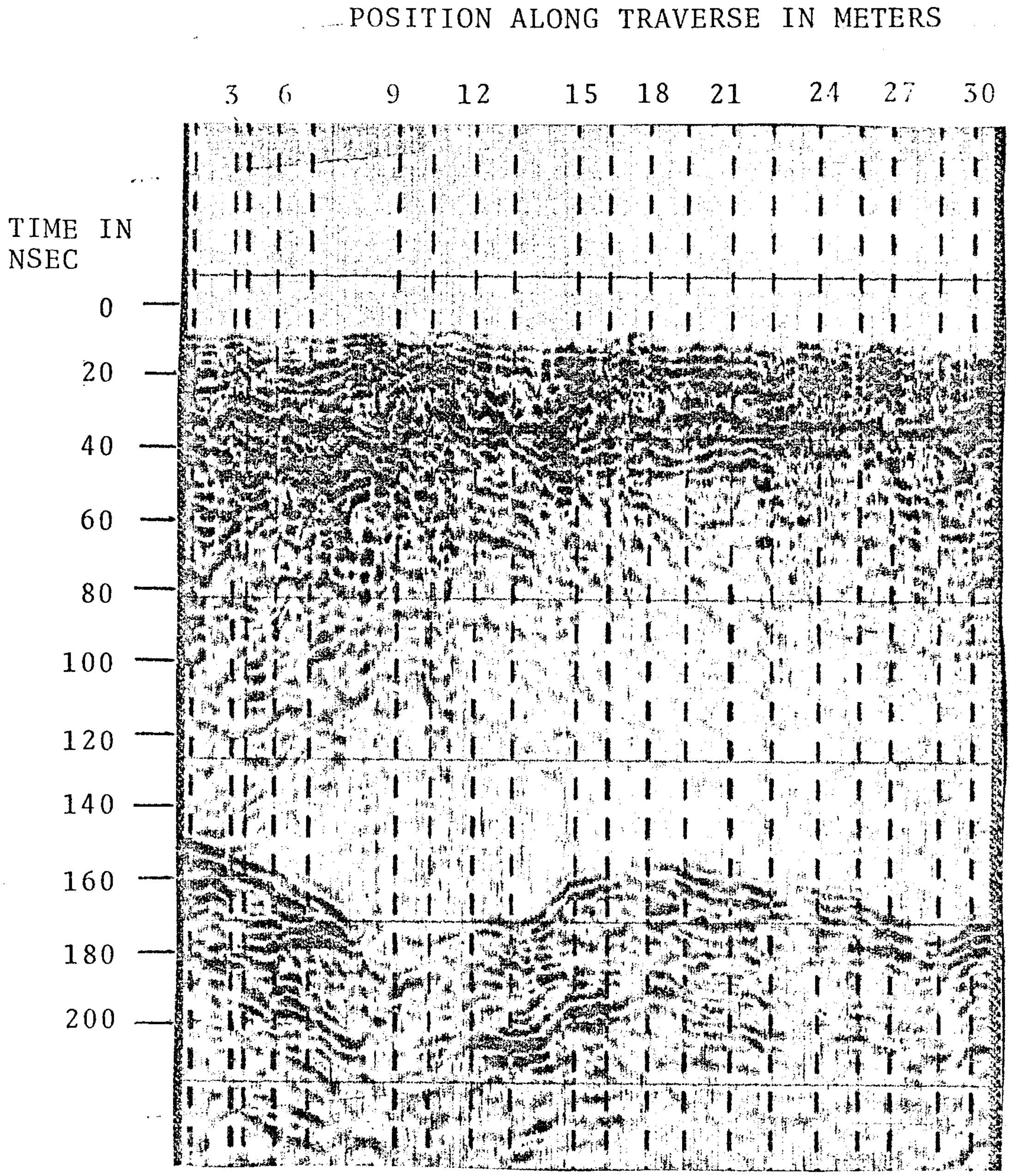
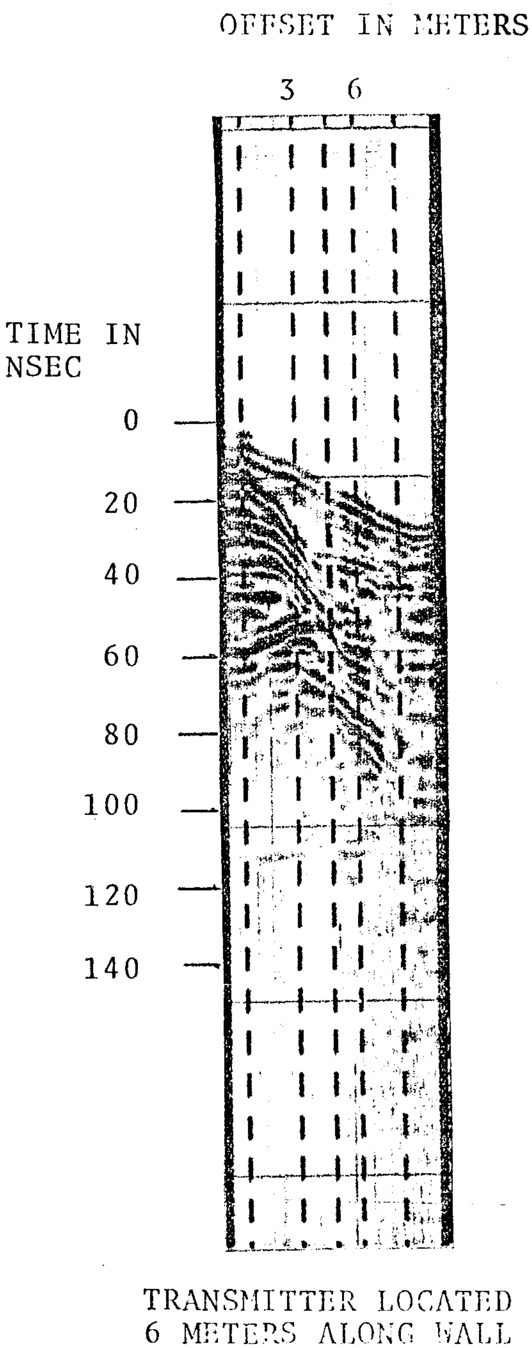


Figure 18. 120 MHz Traverse Along Pillar Site 2
Offset = 3 Meters



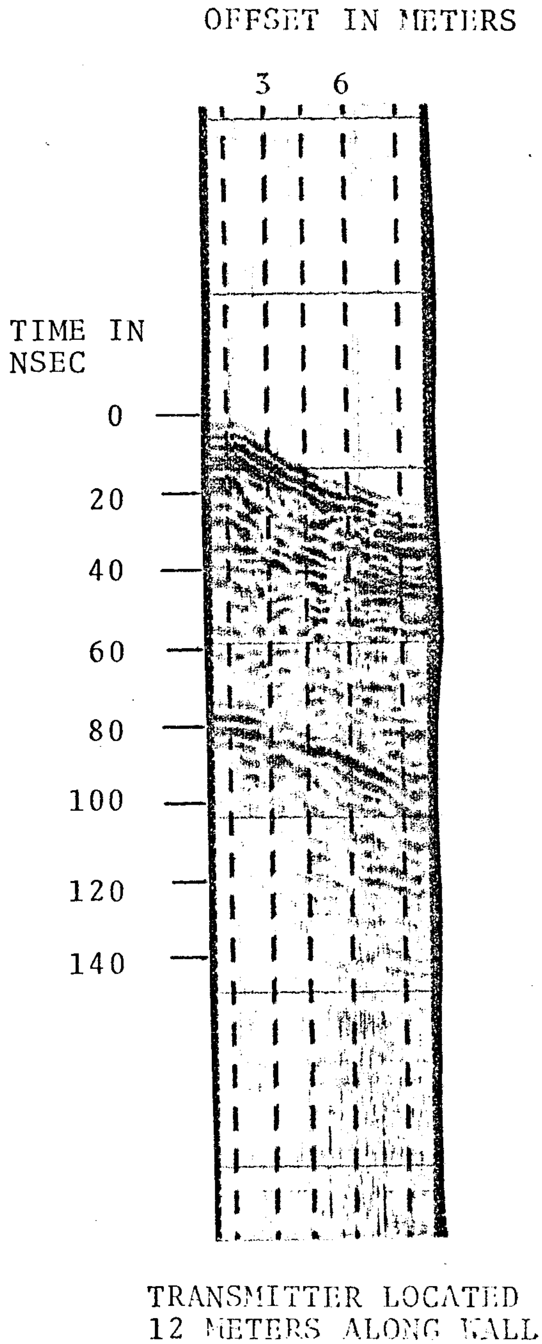


Figure 19. 120 MHz CDP Walkaway Site 3

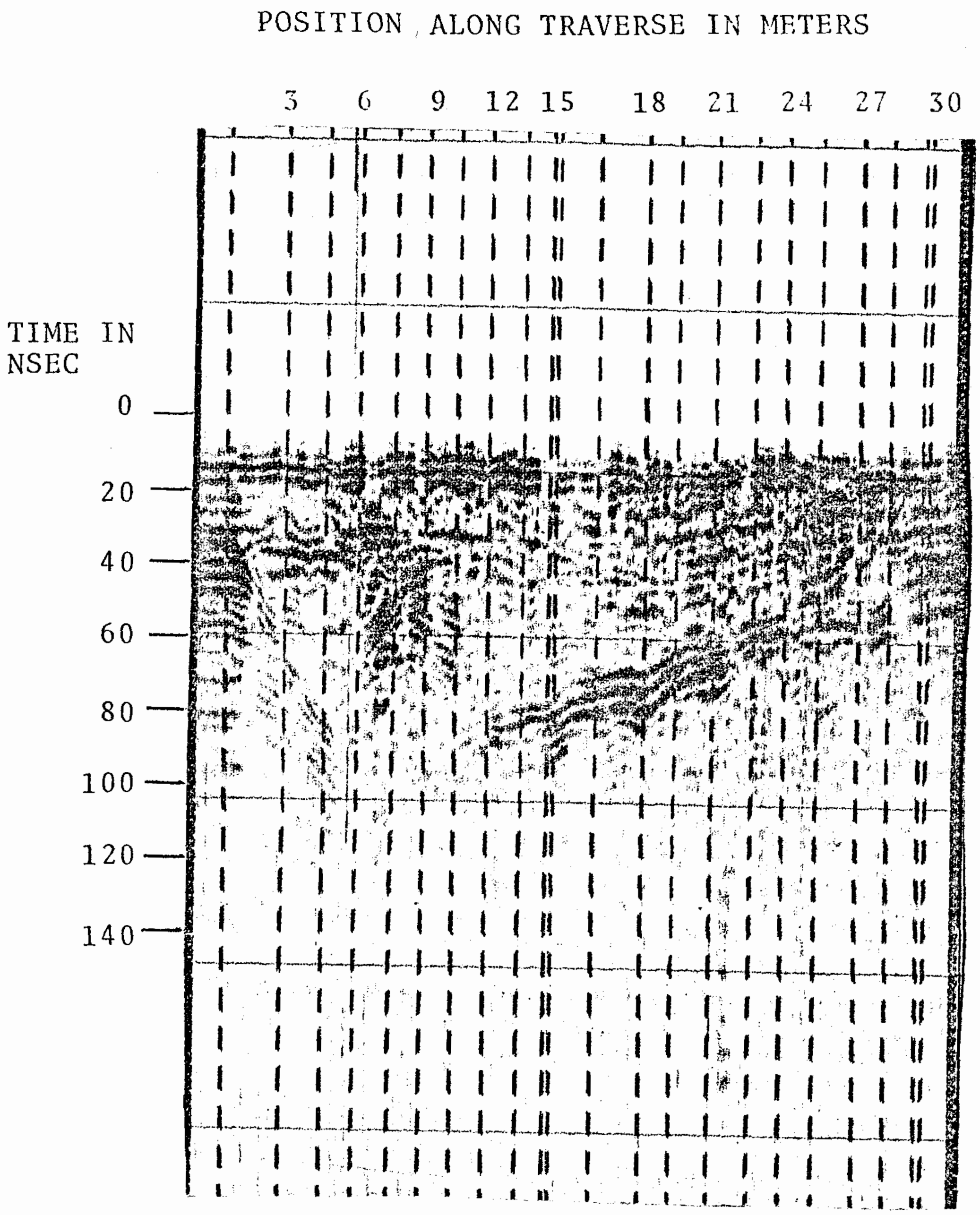


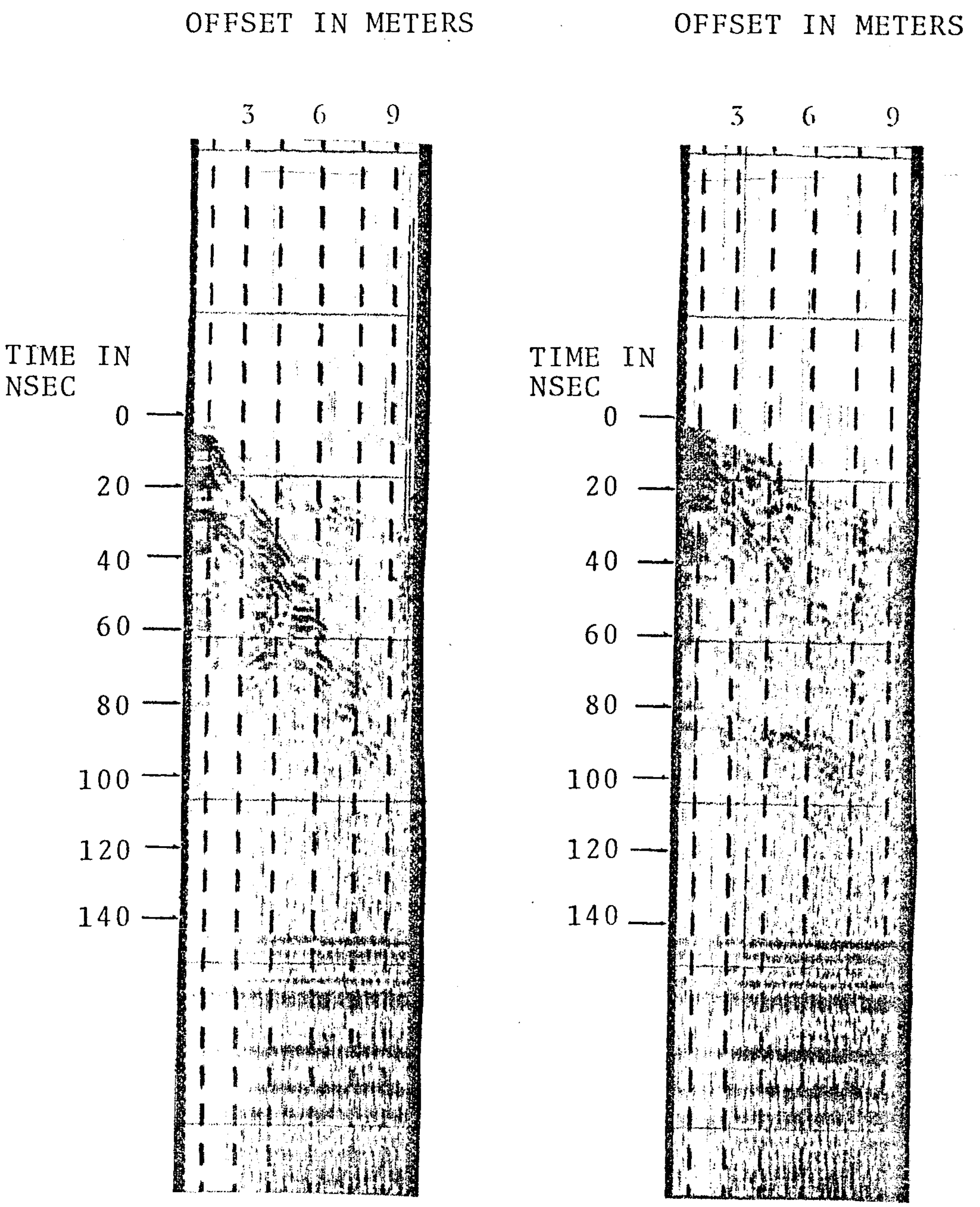
Figure 20. 120 MHz Traverse Site 3
Offset = 3 Meters

The reflection from the corner is seen in the left hand side of the traverse. It moves out very fast as the antenna moves away from the corner. A second major reflection (≈90 nsec) is visible starting about 9 meters along the traverse. This reflection moves toward the edge of the wall very quickly near the end of the traverse. A visual examination of the wall showed that a quartz vein intersects the wall about 10m beyond the end of the traverse. The quartz vein extends from floor to ceiling and is about 10cm thick.

Figures 21 and 22 show the results of the previous two tests when the 350 MHz were used. The results are essentially the same as with the lower frequency antennas except that the signal level is not as high. In both cases, however, the reflection from the vein stands out from the other reflections in that it is stronger in amplitude and it has a definite spatial orientation.

A second quartz vein was located about 100m from Site 3. This vein was also about 10cm thick, however it intersected the tunnel at a much larger angle. Traverses were run with both the 350 MHz and 120 MHz antennas. Figures 23 and 24 show the results of the two tests. The quartz vein intersects the traverse near the zero position. This intersection can be seen in Figure 23 as the reflection moving near the surface from the left end of the traverse. The reflection is not easily seen on Figure 24 because the offset is too large to easily identify reflections near the surface.

The two test sites near the end of the tunnel were in an area of mineralization. The geologic maps show this area as being in the mine sediments. The calculated velocity of .125 meters/nsec is the fastest velocity measured. It corresponds to a dielectric constant of 5.7 which is fairly low. The quartz



TRANSMITTER LOCATED 6 METERS ALONG WALL

TRANSMITTER LOCATED 12 METERS ALONG WALL

Figure 21. 350 MHz CDP Walkaway Site 3

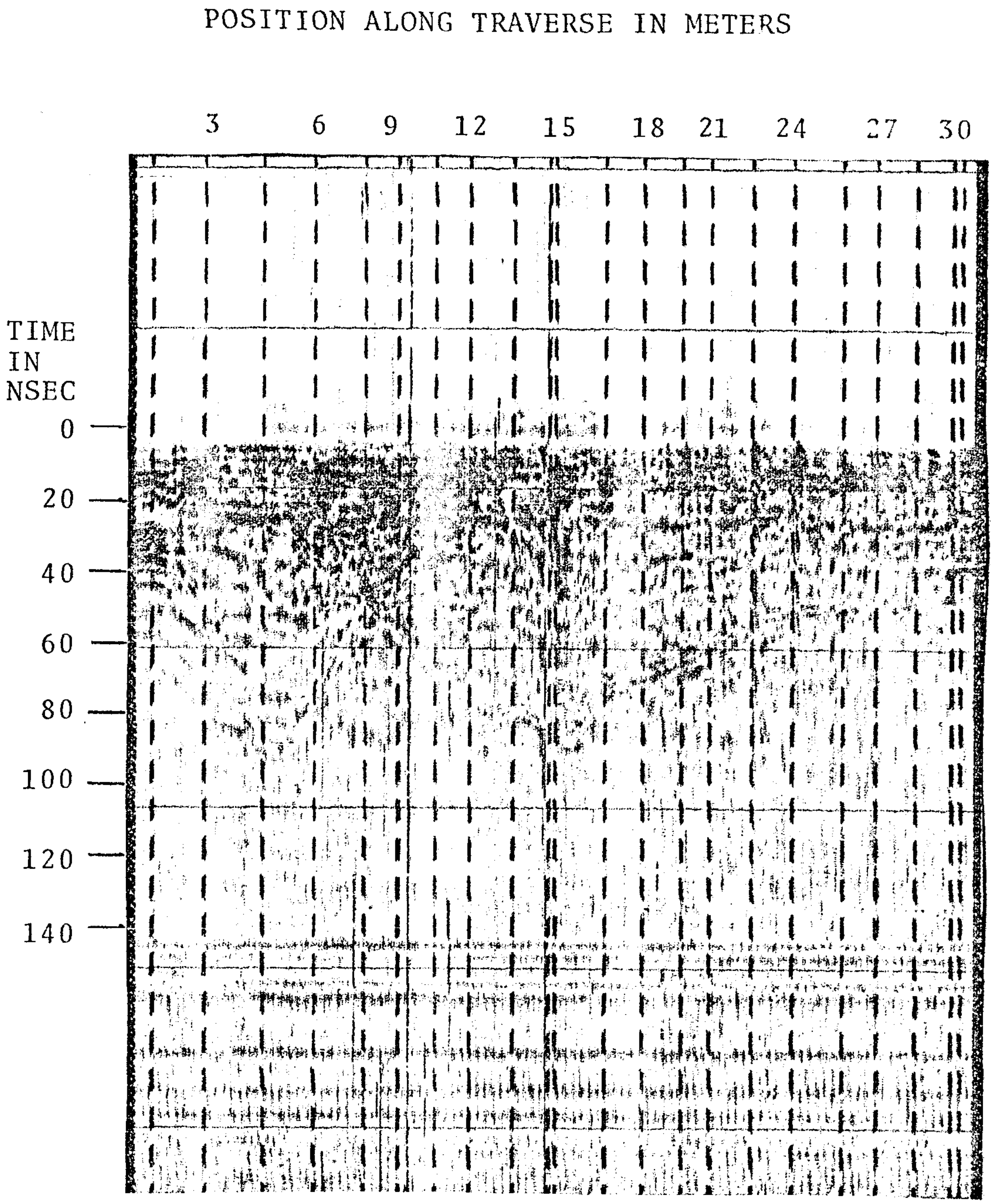


Figure 22. 350 MHz Traverse Site 3
Offset = 1.5 Meters

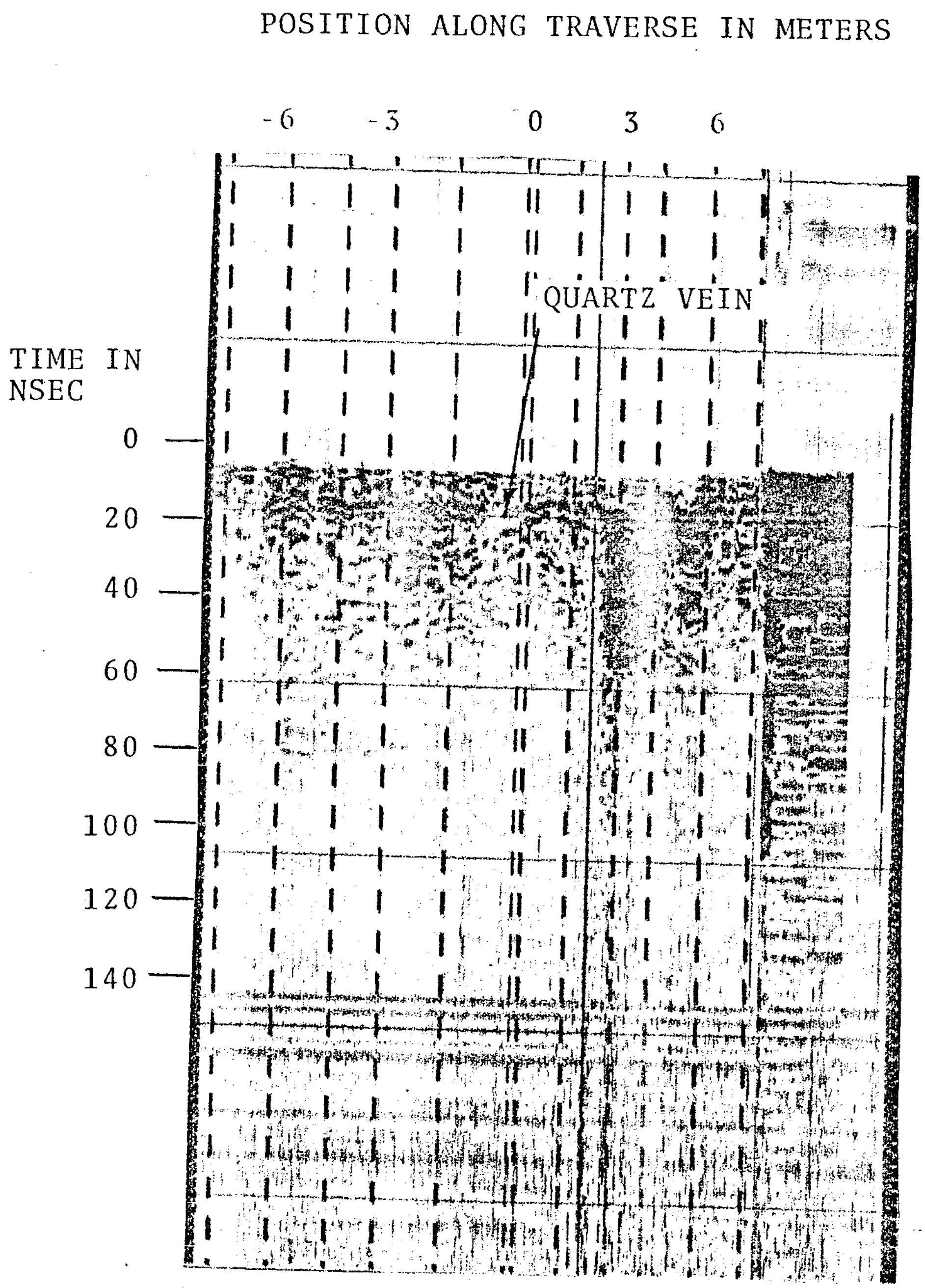


Figure 23. 350 MHz Traverse Site 4
Offset = 1.5 Meters

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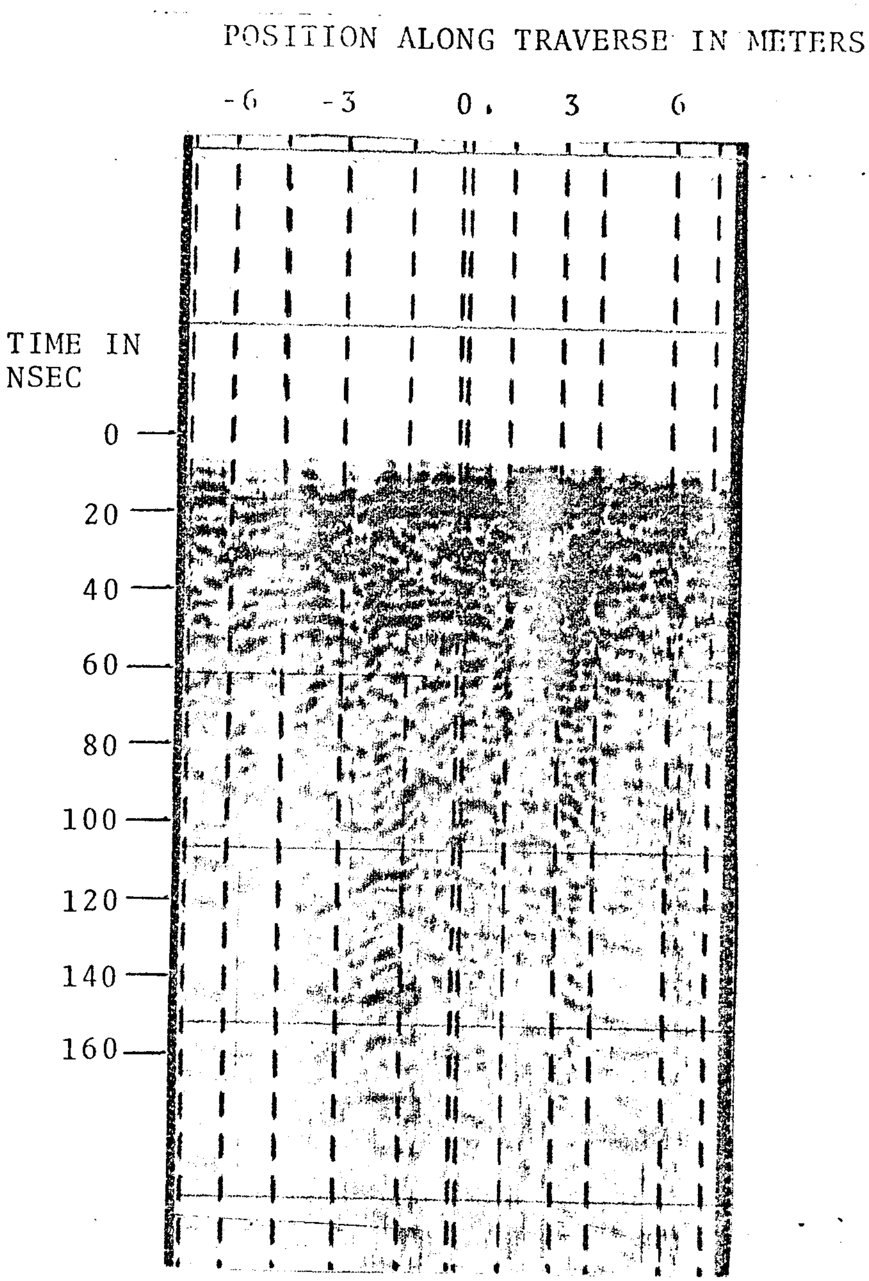


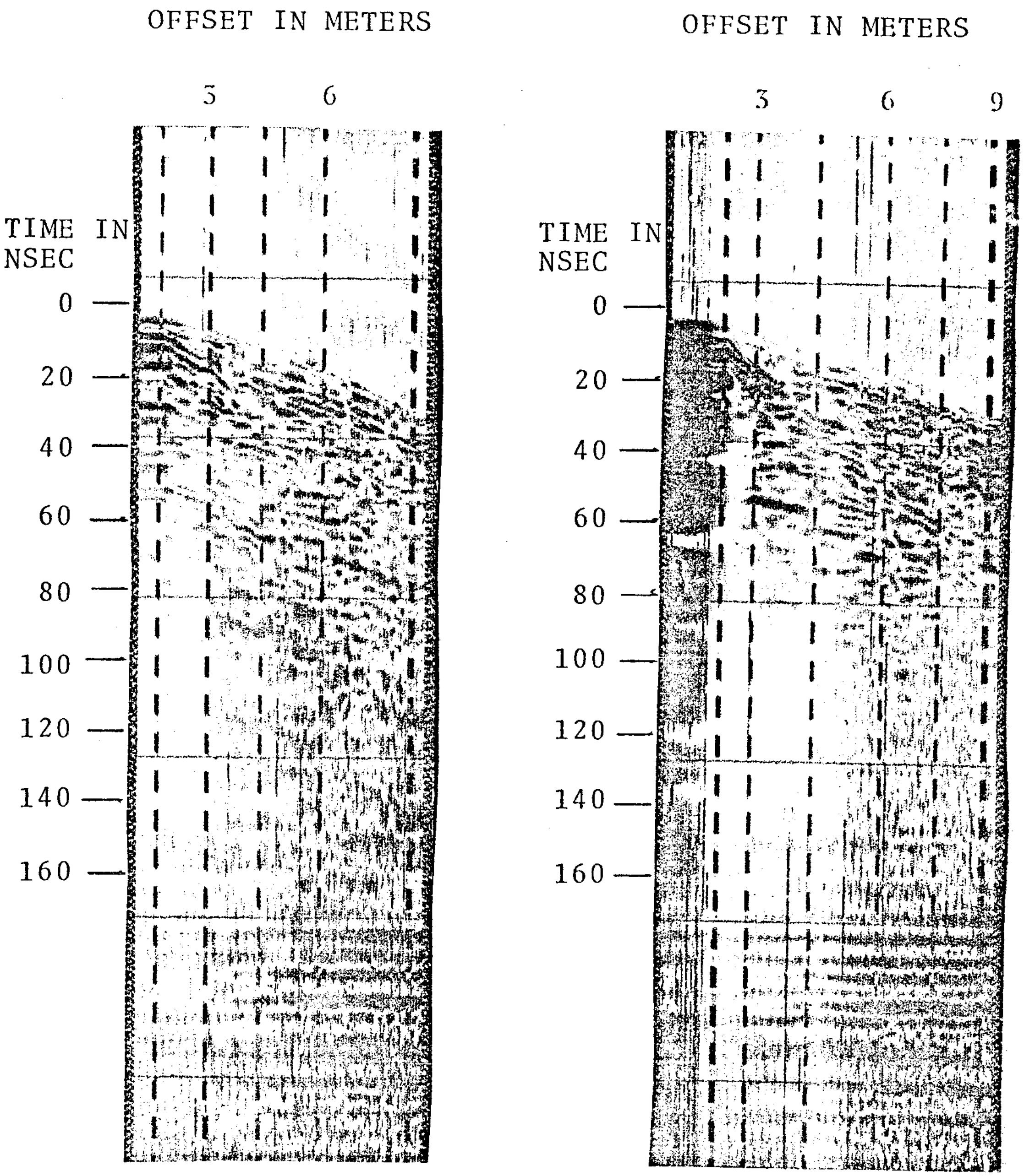
Figure 24. 120 MHz Traverse Site 4
Offset = 3 Meters

veins stand out very well in this low dielectric constant rock. Small reflections from joints in the rock are also visible, however they are much smaller than those from the quartz.

The next four test sites were located in the tunnel in as many of the major rock types as possible. The first site was near the 15,000 feet location in the tunnel. The test location was centered on the zone where the granodiorite changed to a siltstone. The test site covered 60 meters along the wall. The granodiorite extended from the zero position to -30 meters while the siltstone extended from 0 to 30 meters. Figures 25 and 26 show CDP walkaway tests in the two different types of rock. All of the sites show a lack of a large continuous reflector in the wall. The velocity of the shallow (near 60 nsec) reflector at the 6 meters site is .122 m/nsec while the velocity of the reflector near 70 nsec at the -12m site is .118 m/nsec. The difference in these two velocities is very slight, however the velocity in the siltstone is faster than in the granodiorite. The absence of a large identifiable reflector makes the accurate measurement of the velocity difficult.

Figures 27 and 28 show the 350 MHz traverse along the wall. Several definite reflection zones can be seen. The first is the reflection which starts near the 27 meter mark and gets deep as the radar moves toward zero. The second starts about 60 nsec deep at the 9 meter mark and gets shallower as the radar moves toward zero. This second reflection zone is probably associated with the change of rock type. The traverse from zero to -30 meters shows no organized reflection zones.

Figures 29 and 30 show the same traverses with the low frequency antennas. These figures show essentially the same reflections as the previous two figures. The deeper penetration of the 120 MHz radar does not show any major reflection zone



TRANSMITTER LOCATED AT 6 METERS

TRANSMITTER LOCATED AT 12 METERS

Figure 25. 350 MHz CDP Walkaway Site 5

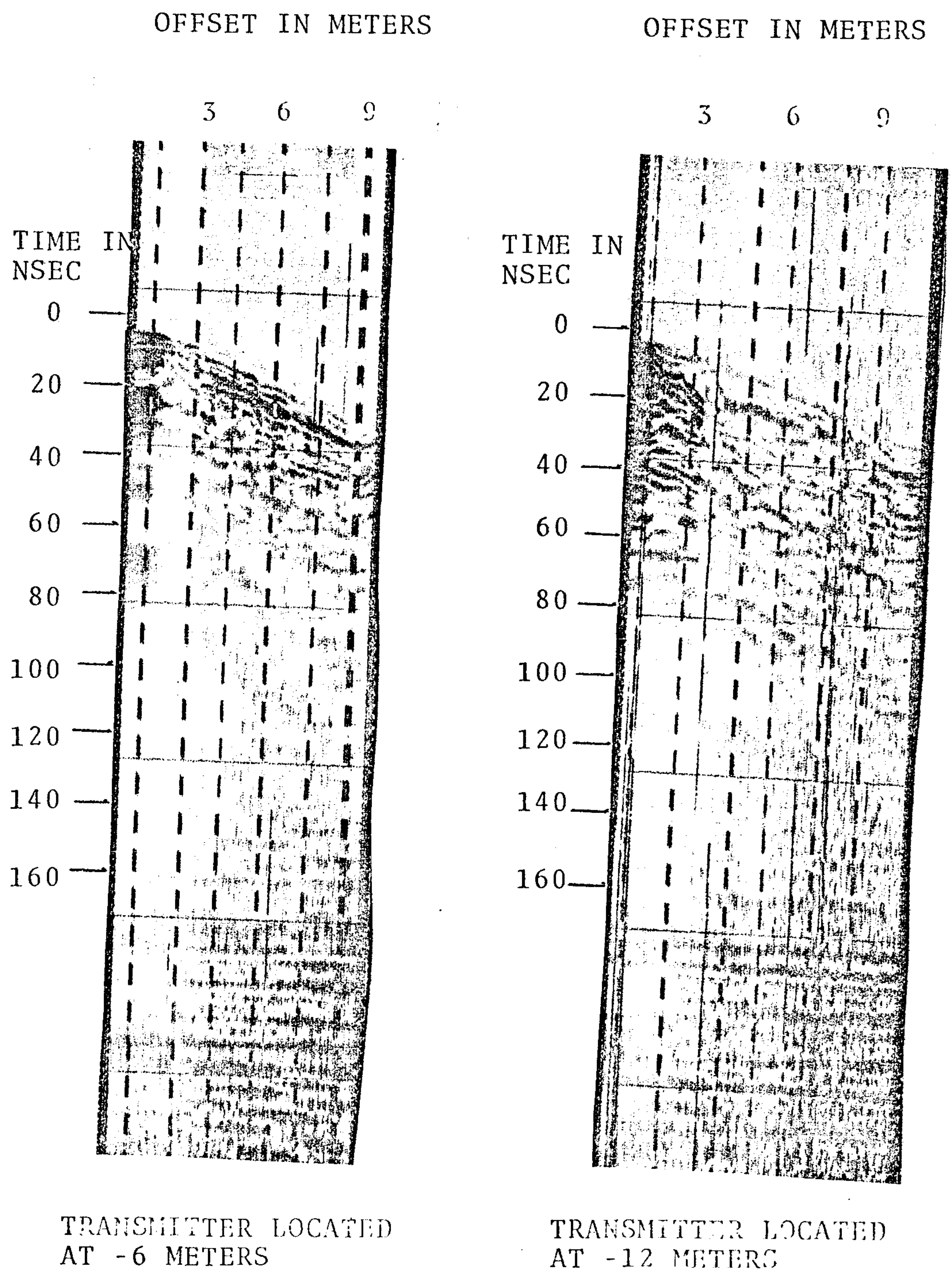


Figure 26. 350 MHz CDP Walkaway Site 5

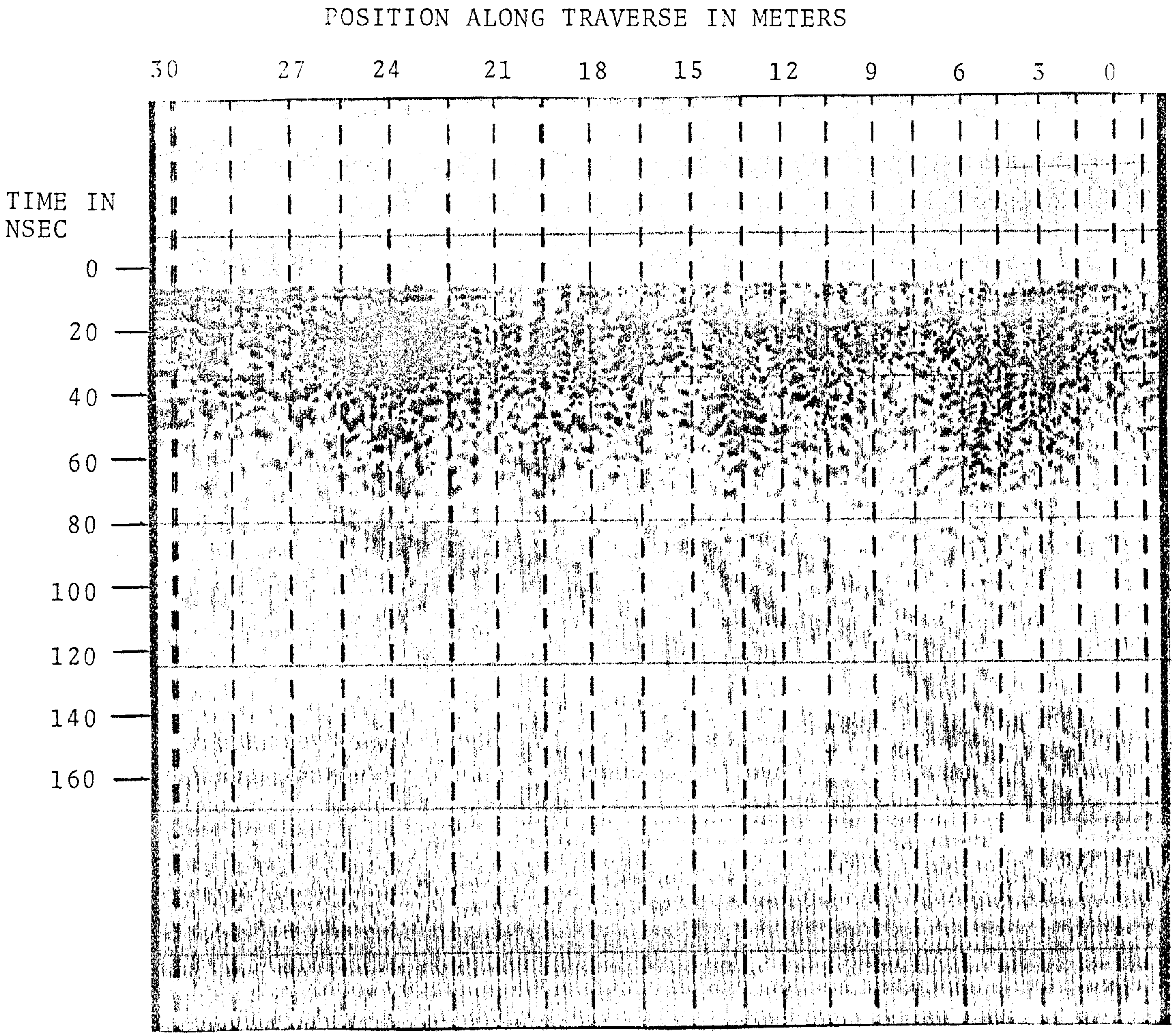


Figure 27. 350 MHz Traverse Site 5
Offset = 1.5 Meters

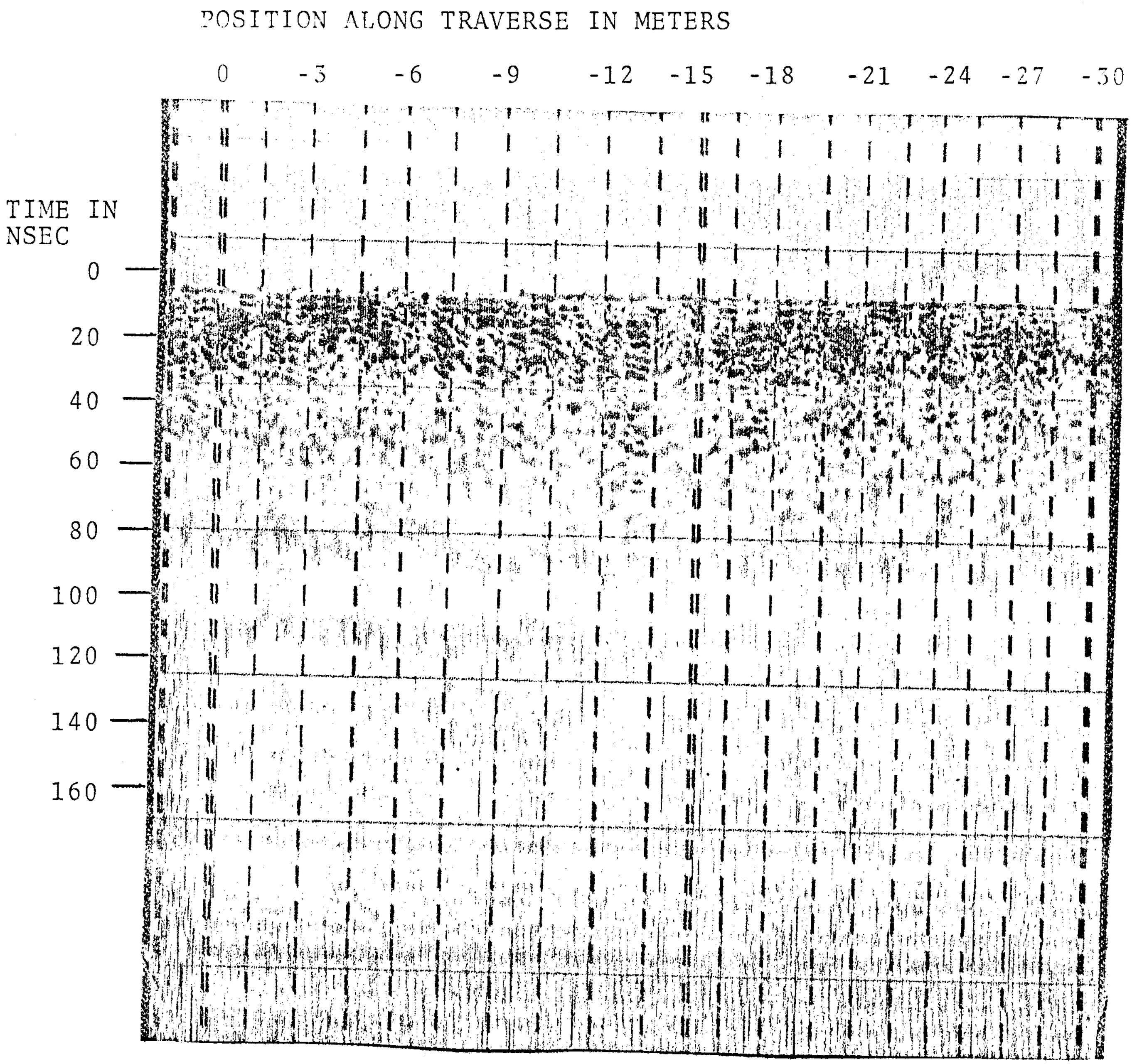


Figure 28. 350 MHz Traverse Site 5
Offset = 1.5 Meters

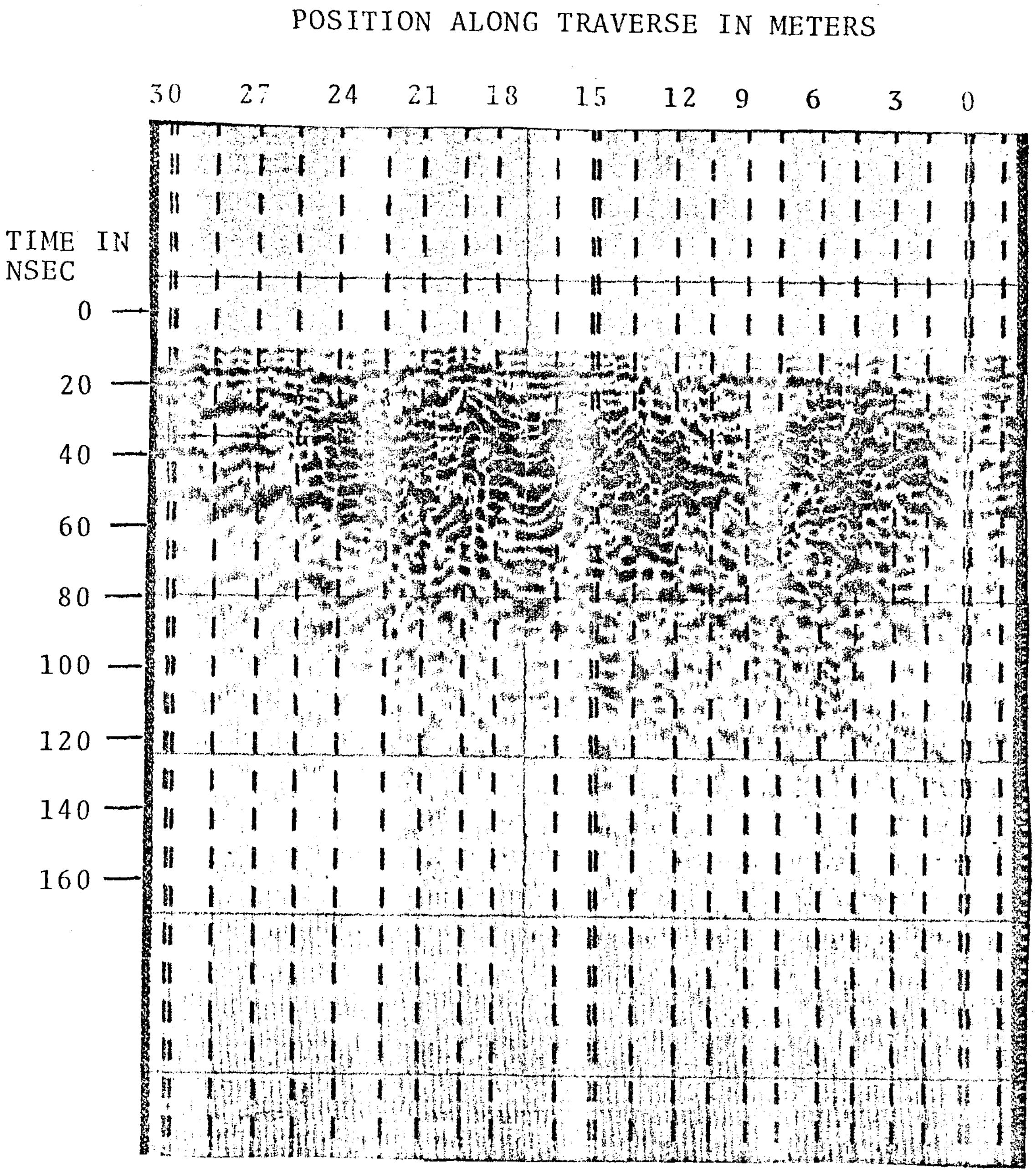


Figure 29. 120 MHz Traverse Site 5
Offset = 3 Meters

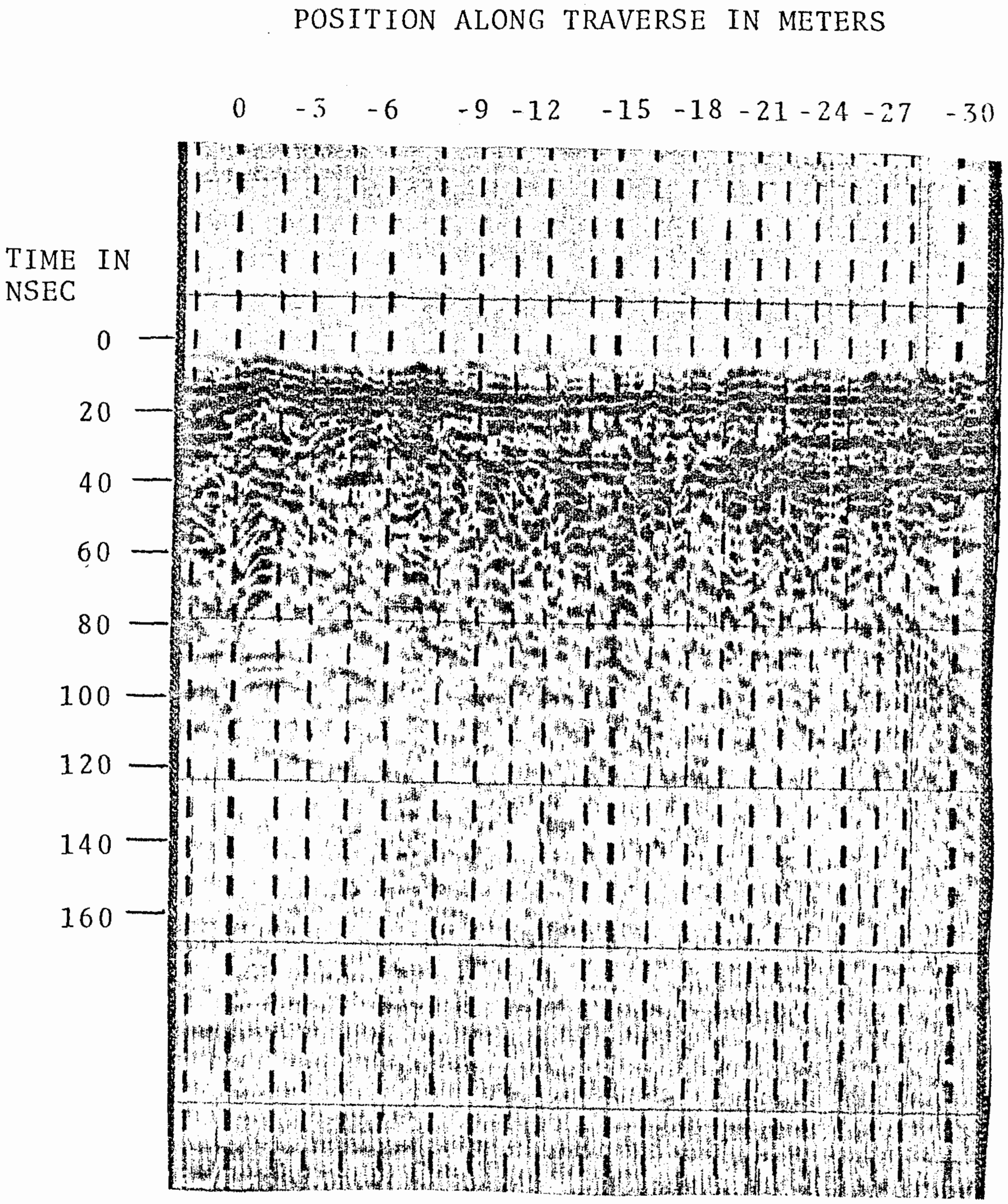


Figure 30. 120 MHz Traverse Site 5
Offset = 3 Meters

at depth. Thus both rock types in this area have fracturing which shows up as small reflections along the traverse. No major faults or fracture zones are visible on the records.

The next test site (Site 6) was at the 40,000 feet mark of the tunnel. The rock type at this site was a diabase. The tests were conducted along a 30 meter length of the wall. Figures 31 and 32 show the CDP walkaways for this test site. There are no reflections seen on these records except for a possible reflection at 110 ns on the 120 MHz test at 12 meters. This velocity calculated from this refleciton is .120 m/nsec. Figures 33 and 34 show the two traverses. The solid band of apparent reflection going straight across the record is from reverberation in the tunnel and indicate that either the rock is extremely conductive and the energy is not penetrating the rock or that the rock has almost no fractures or joints in it.

Test Site 7 was at the 35,000 feet position in the tunnel. The geologic map shows that the rock at this site is a pillow lava. Again as at the previous site, a 30 meter section of wall was marked for the radar traverse. The walkaway tests are shown in Figures 35 and 36. This site has more returns from reflectors in the wall than at the previous site. The velocity to the reflector at the 105 ns level of the 12 meter walkaway is 0.111 m/nsec. Figures 37 and 38 show the two traverses made at this site. No major reflections can be seen in the wall here, but more fractures and joints can be seen than at the previous site.

The final test site was at the 30,000 feet position. The rock type at this final site was a greenschist. The CDP walkaway tests are shown in Figures 39 and 40. There are few returns on these records and the only velocity calculation was from the return at 60 nsec on the 12 meter walkaway in Figure 40. The velocity to this reflector is 0.08 m/nsec which is the slowest velocity measured at this mine. The two traverses

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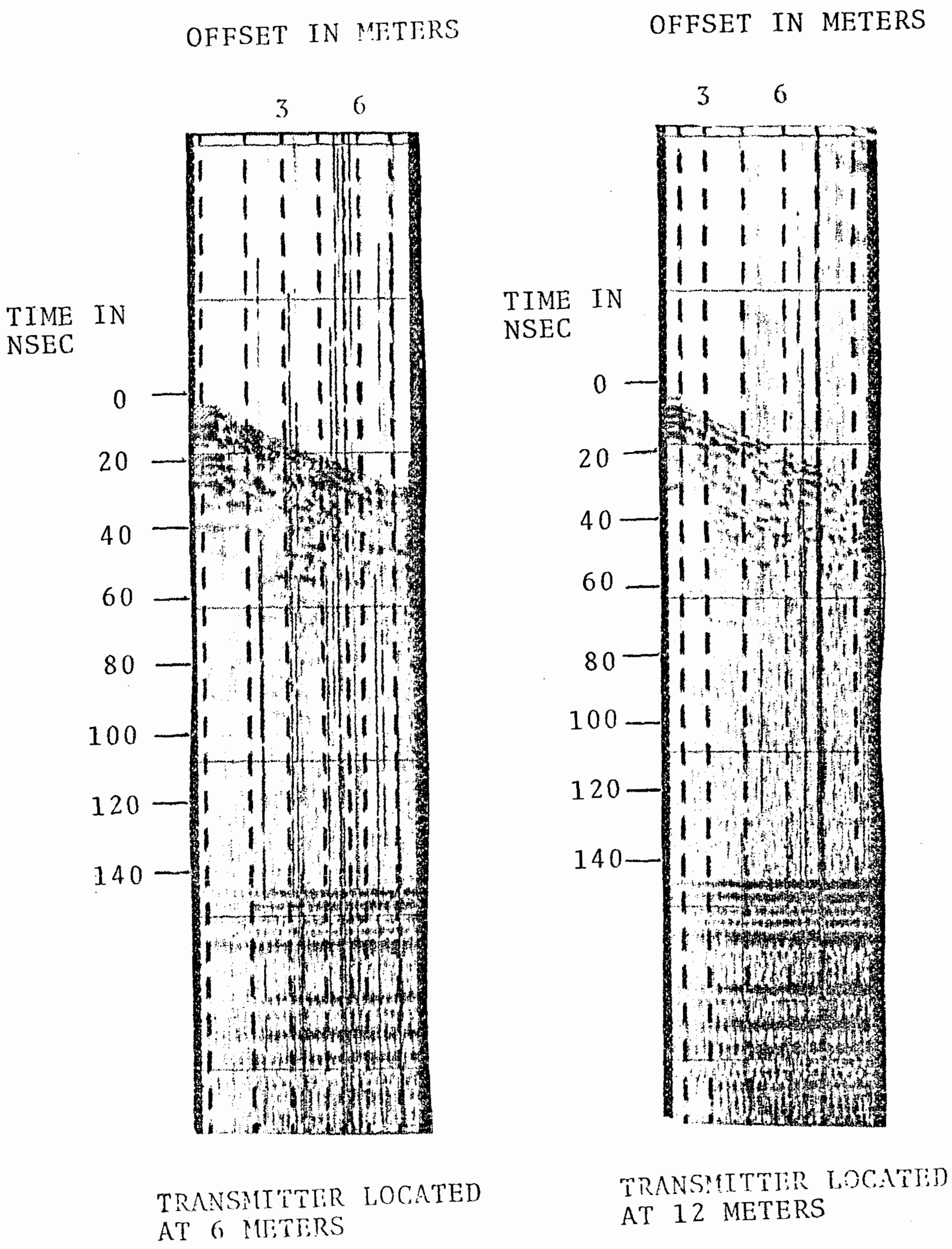
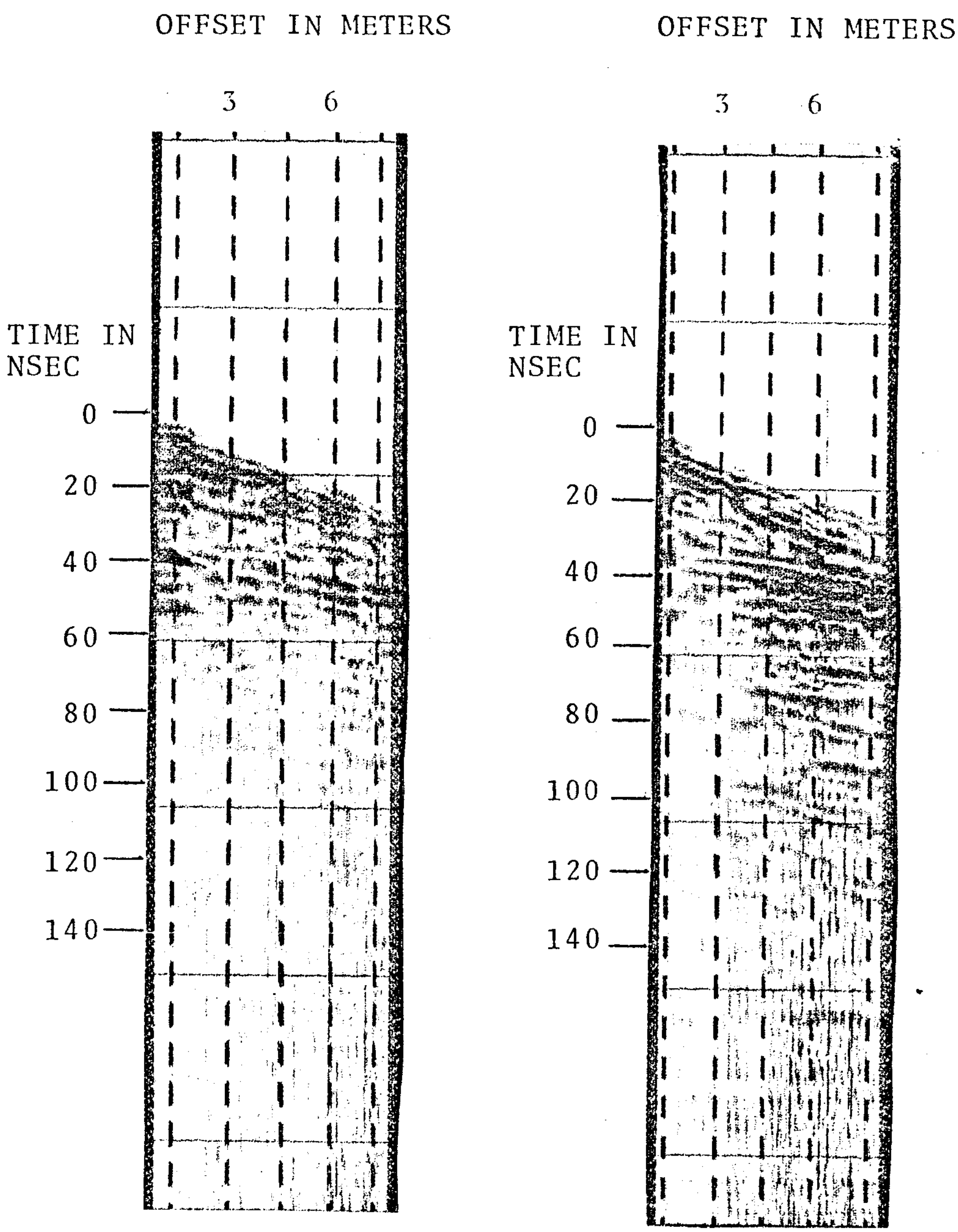


Figure 31. 350 MHz CDP Walkaway Site 6



TRANSMITTER LOCATED AT 6 METERS

TRANSMITTER LOCATED AT 12 METERS

Figure 32. 120 MHz CDP Walkaway Site 6

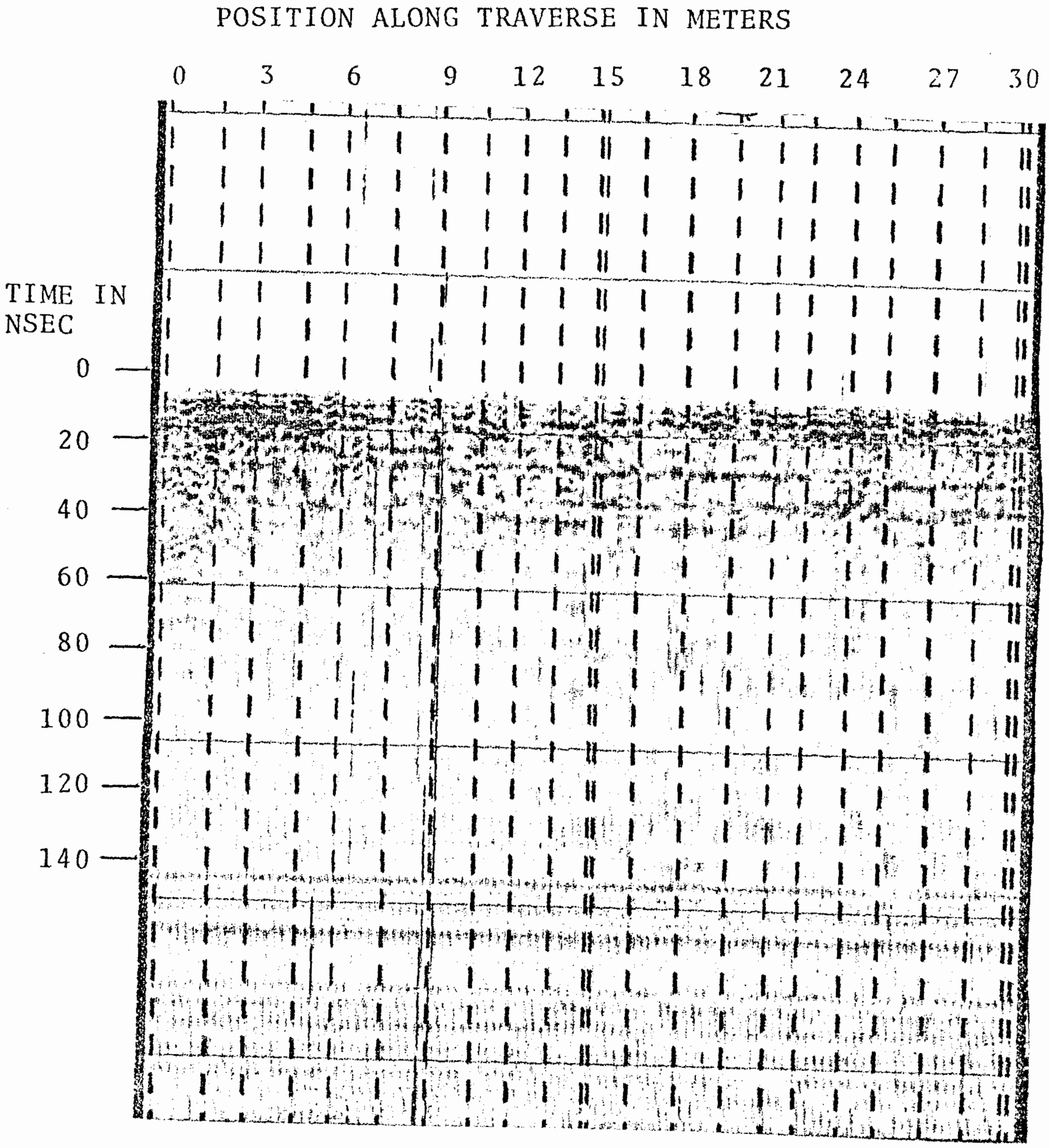


Figure 33. 350 MHz Traverse Site 6
Offset = 1.5 Meters

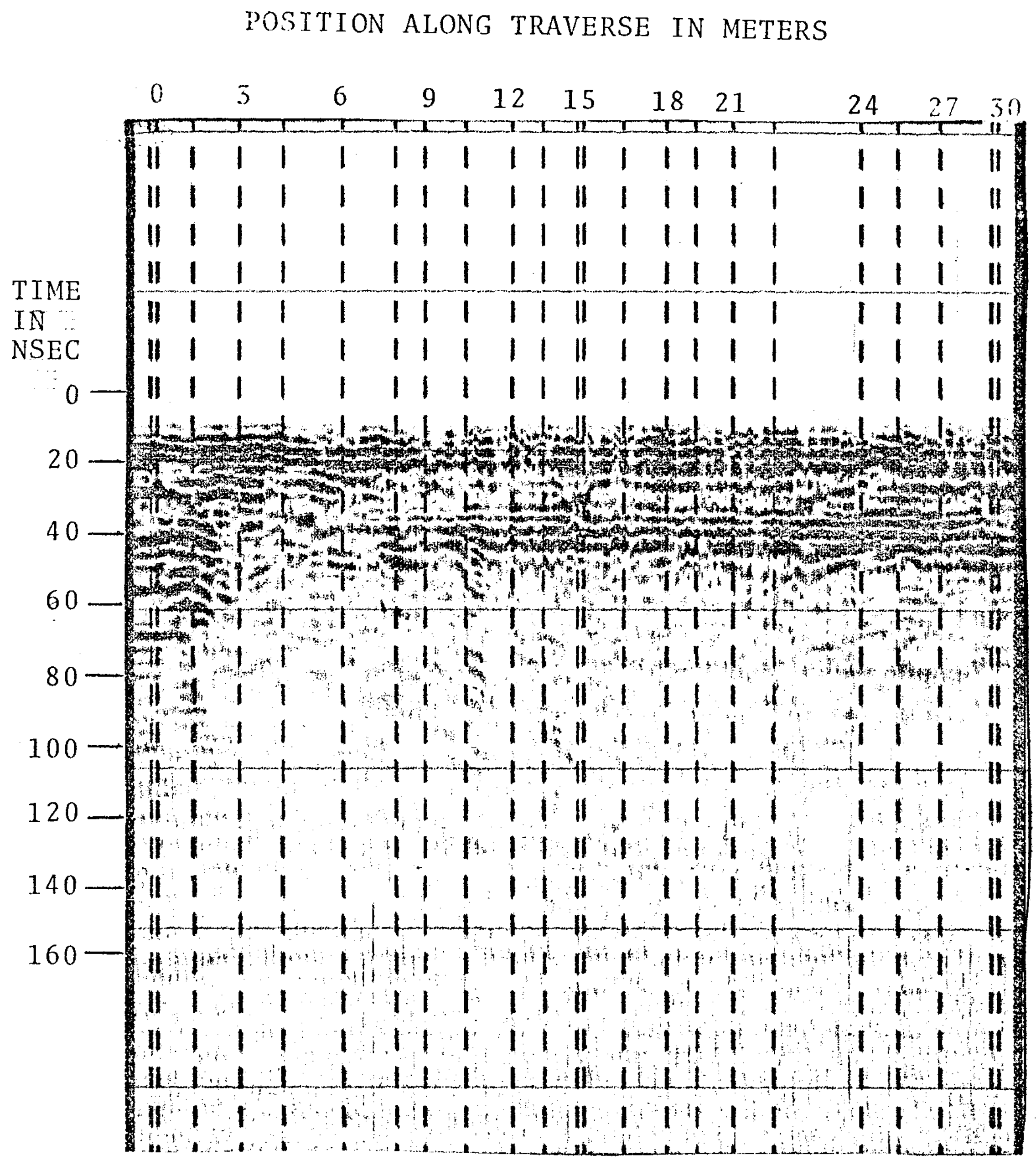


Figure 34. 120 MHz Traverse Site 6
Offset = 3 Meters

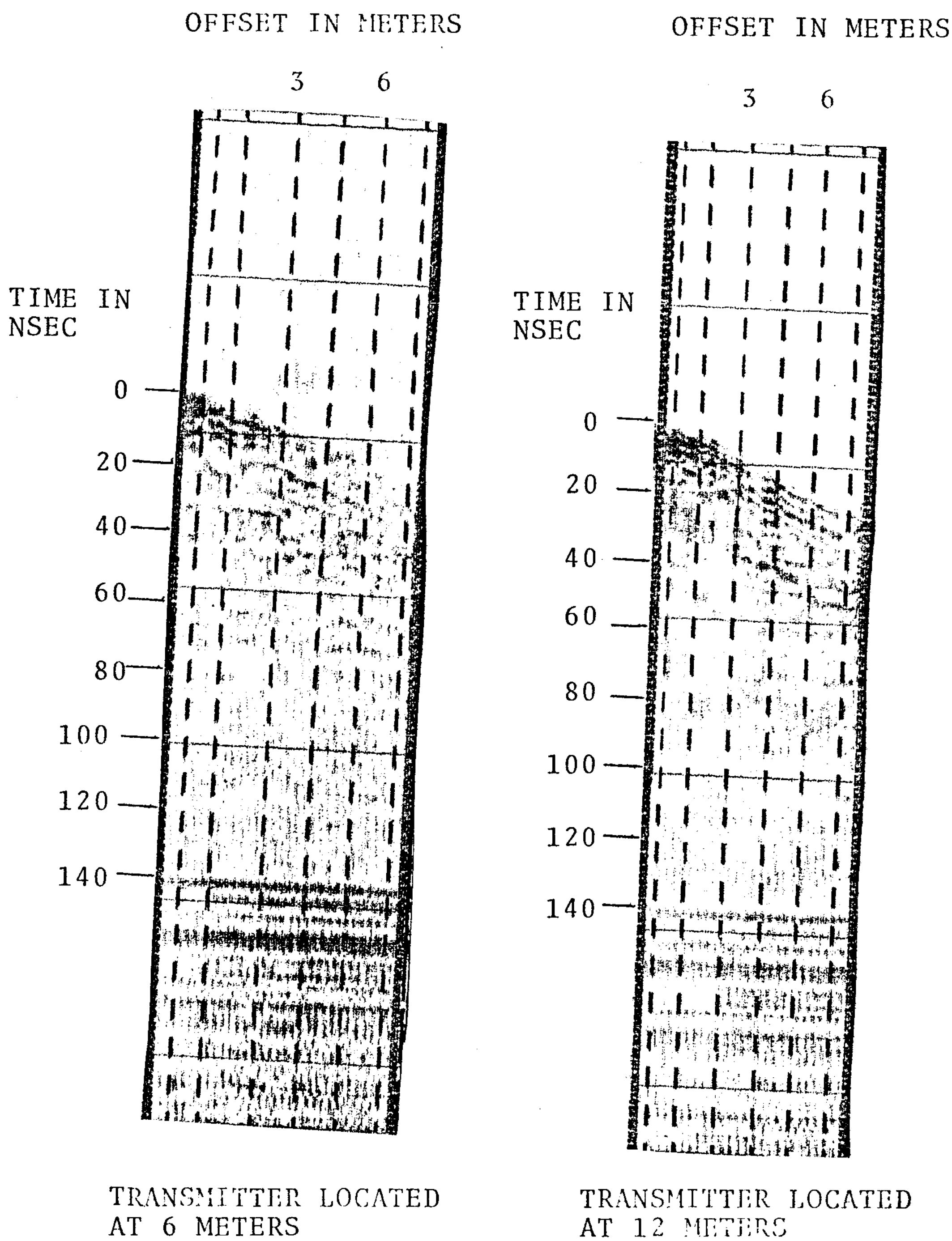


Figure 35. 350 MHz CDP Walkaway Site 7

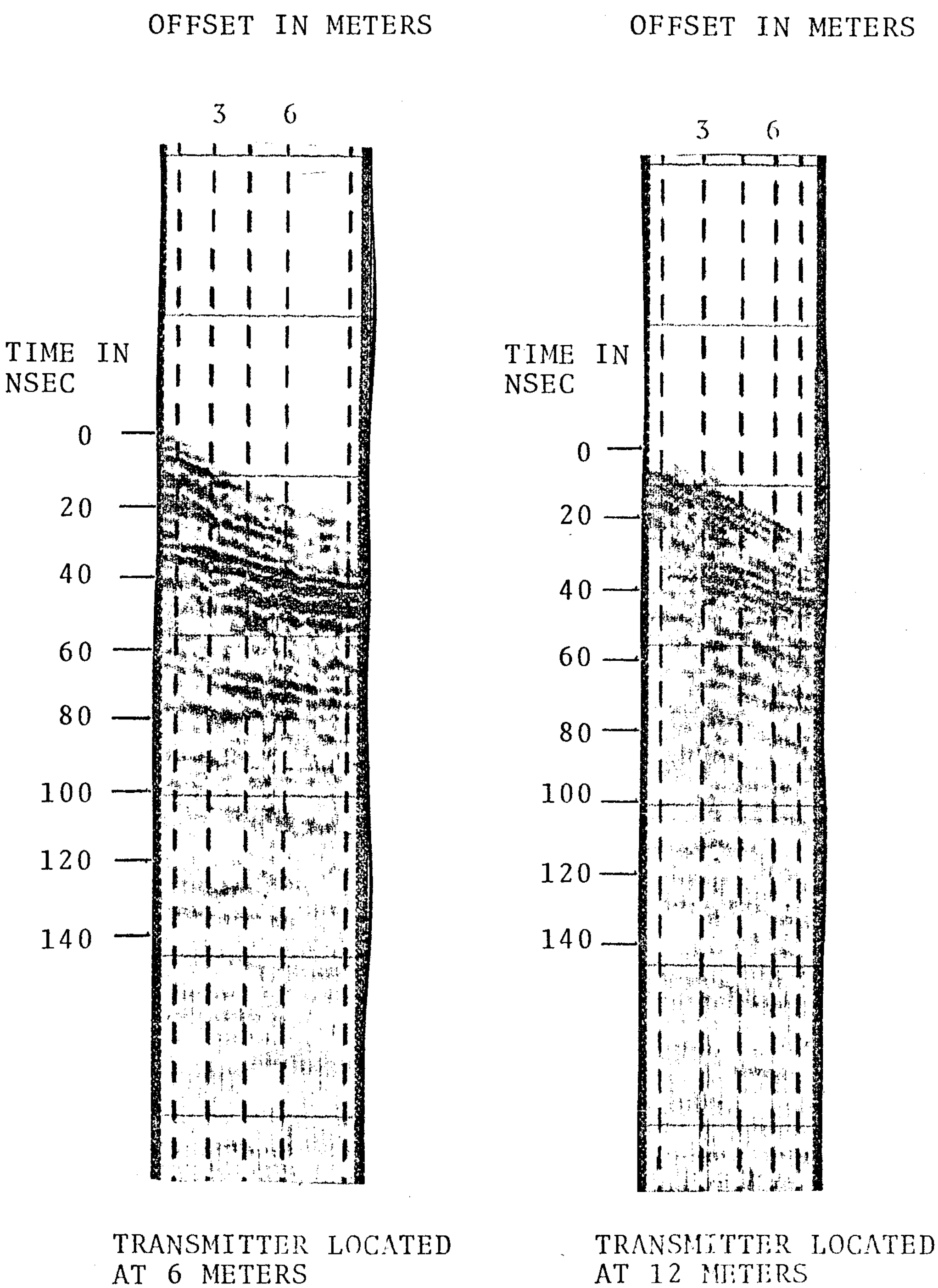


Figure 36. 120 MHz CDP Walkaway Site 7

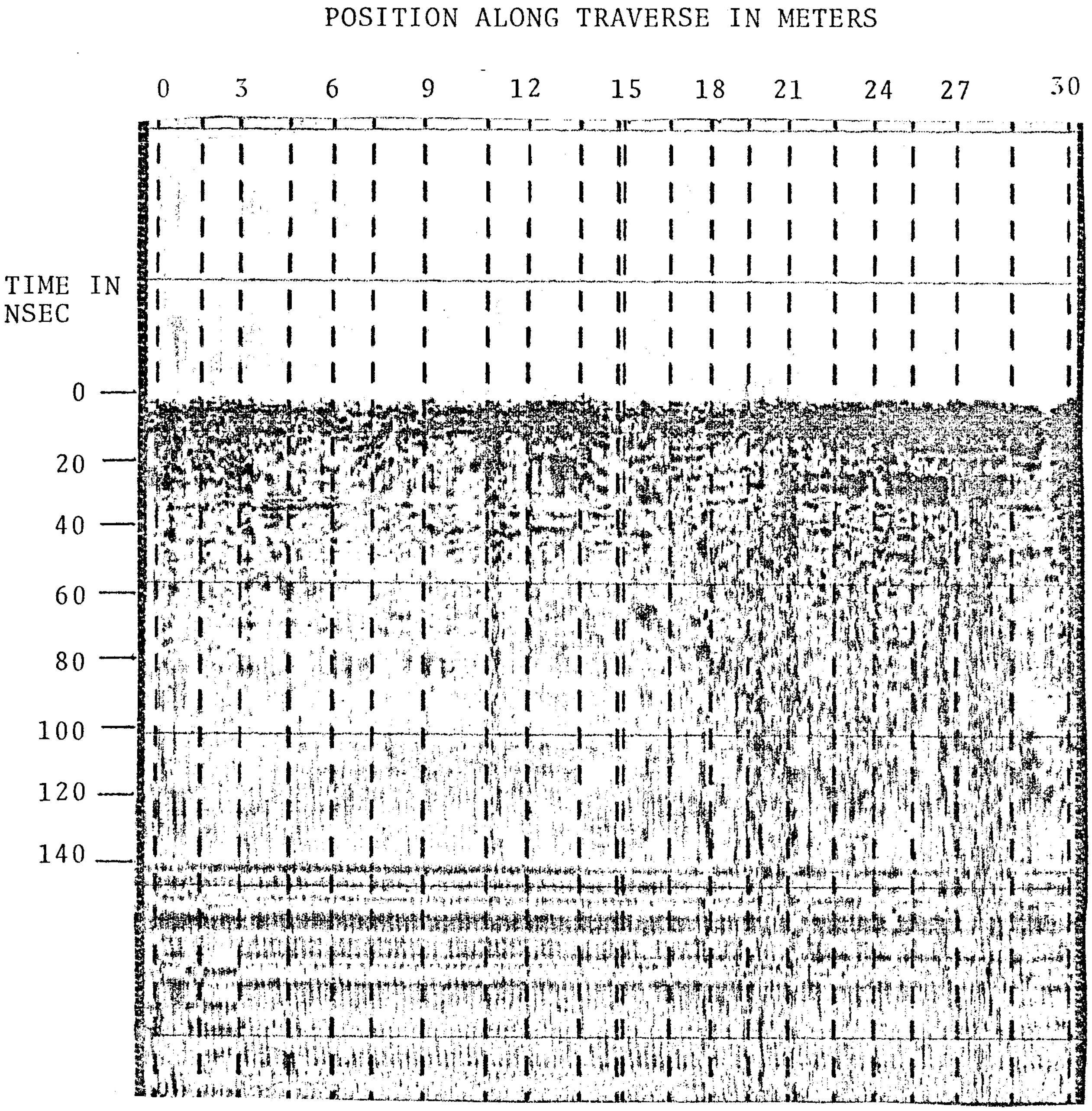


Figure 37. 350 MHz Traverse Site 7
Offset = 1.5 Meters

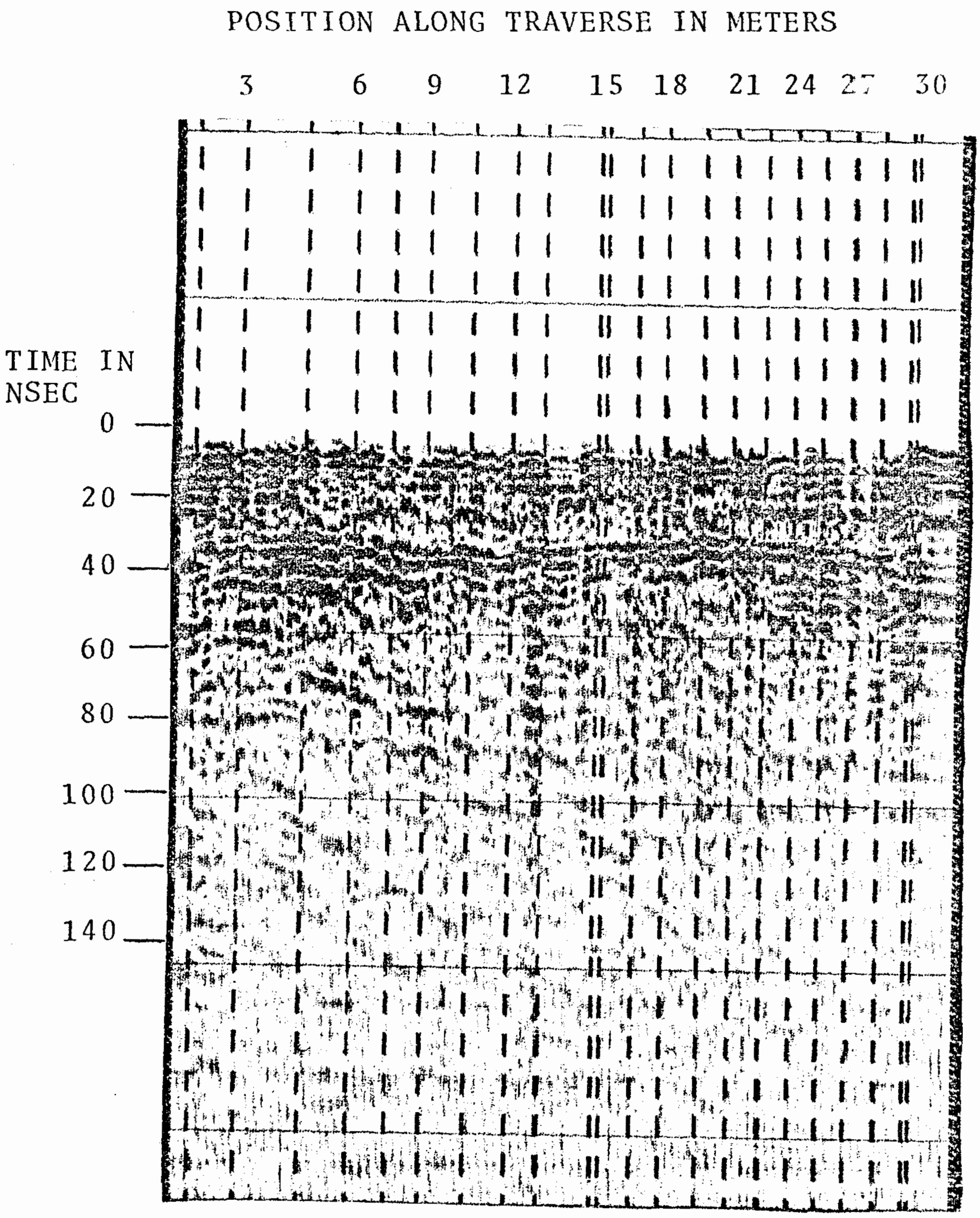
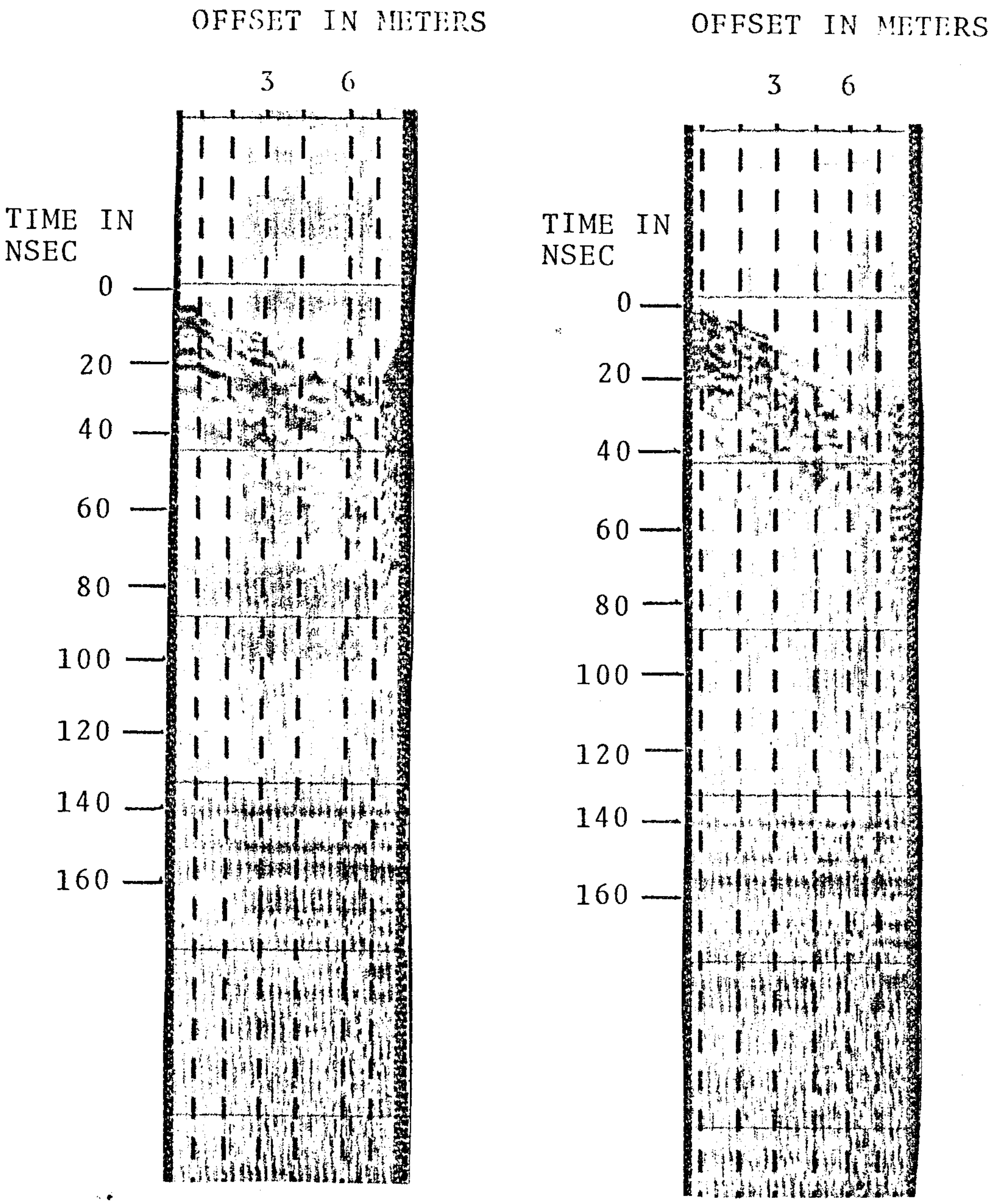


Figure 38. 120 MHz Traverse Site 7
Offset = 3 Meters



TRANSMITTER LOCATED AT 6 METERS

TRANSMITTER LOCATED AT 12 METERS

Figure 39. 350 MHz CDP Walkaway Site 8

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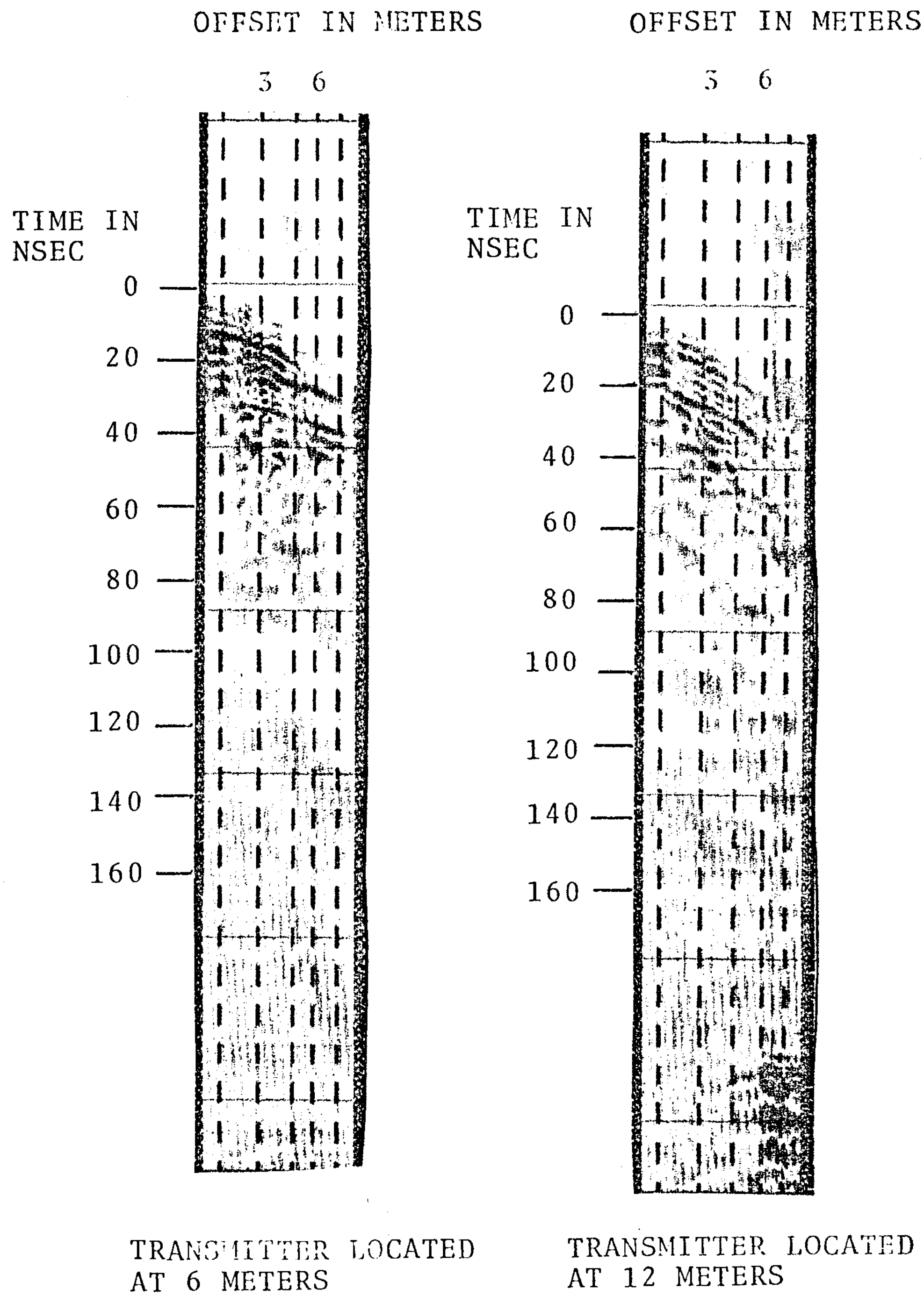

Figure 40. 120 MHz CDP Walkaway
Site 8

are shown in Figures 41 and 42. These records show a reflector intersecting the tunnel wall at the 12 meter location. This reflection is characterized by a definite change in signal characteristics over a width of about one meter, therefore it is probably from a joint zone in the wall.

3. CONCLUSIONS AND RECOMMENDATIONS

The radar tests were designed to evaluate the radar system in the mine environment and to provide information on the electrical properties of the rocks in the Granduc Mine. The electrical properties of interest include the bulk dielectric properties and geologic features such as quartz veins and fracturing. These geologic features provide paths for water migration and therefore are often associated with the mineralization in this area.

The results of the tests are summarized in Table I. All of the test sites were fairly easy to evaluate except for Site 6. The inability to see reflectors from within the wall at this site made it impossible to determine whether the radar was penetrating the rock. A transillumination test in this rock type would have made it possible to measure penetration distances. However, this was not possible. Therefore, a question mark is included in the table in the joint column. The deepest penetration was obtained in the mine sediments.

The quartz veins produced extremely strong reflections and were traced to depths in excess of 6.5 meters. Since the quartz vein reflection is as strong as the rock/air reflection, it is reasonable to assume that this unit could trace the reflections to depths on the order of 10 meters in areas similar to Site 2. The ability to see fracturing is important from two standpoints. First, the fractures provide the path for the water and are therefore the areas where the minerals are deposited. Secondly, pillars with a high degree of fracturing are more unstable and therefore subject to rock

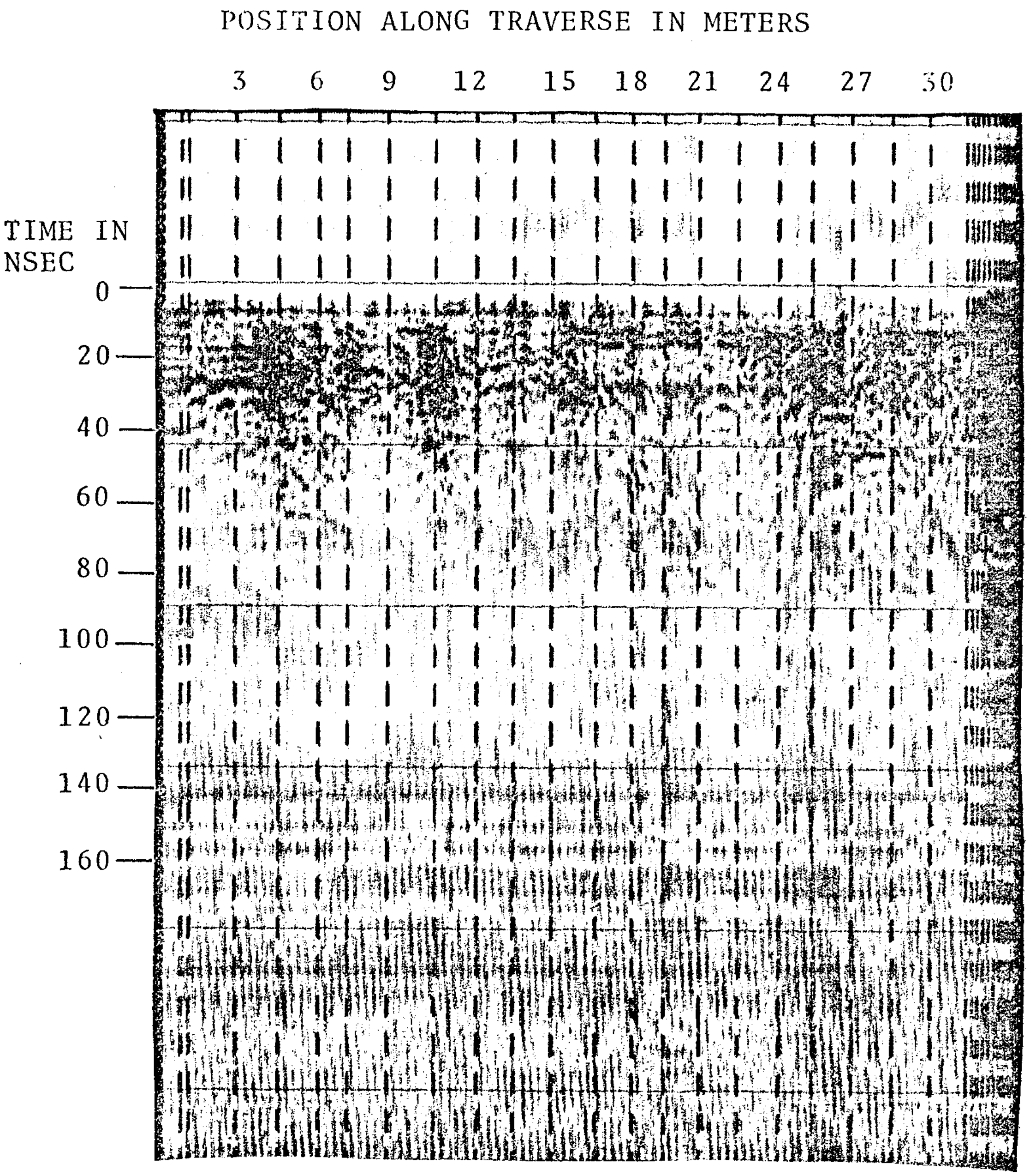

Figure 41. 350 MHz Traverse Site 8
Offset = 1.5 Meters

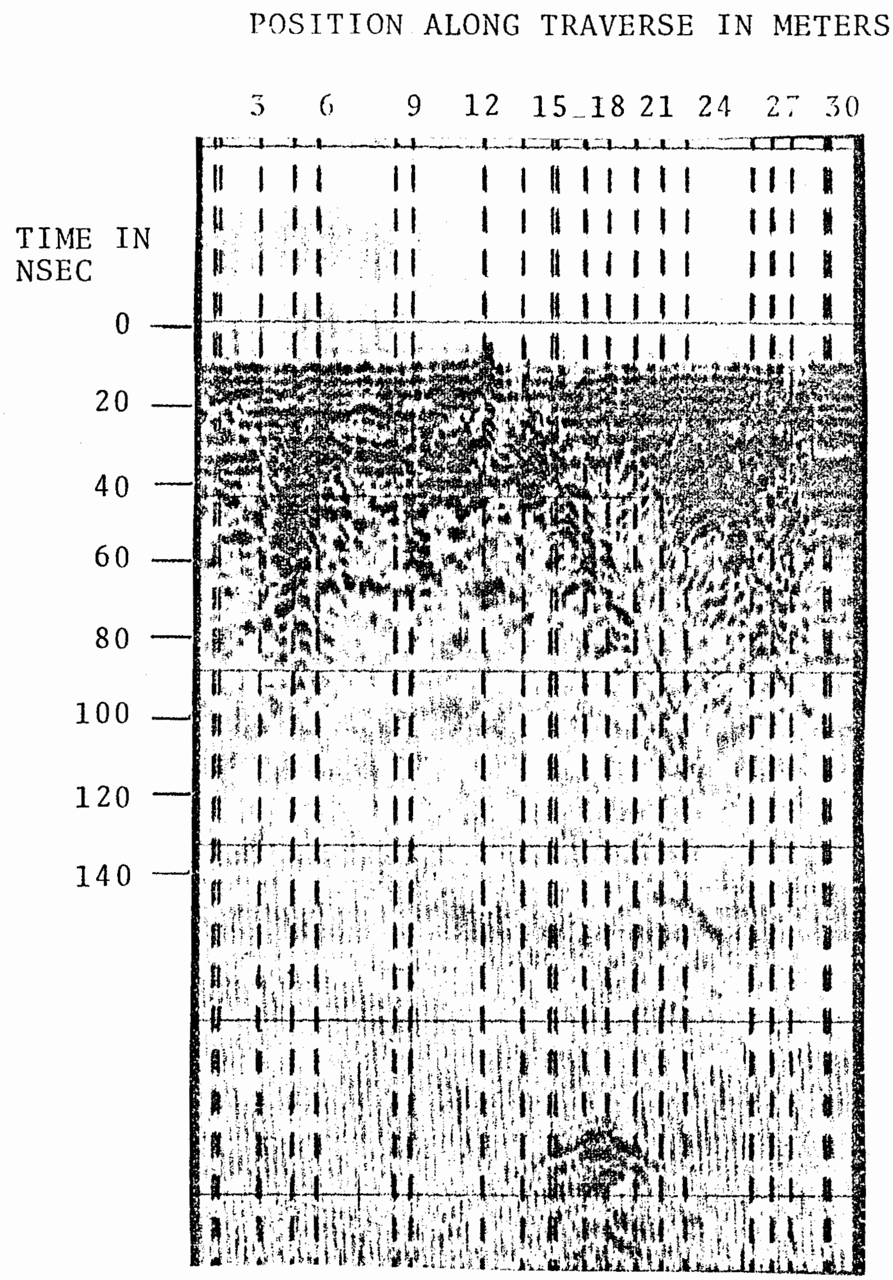

Figure 42. 120 MHz Traverse Site 8
Offset = 3 Meters

bursts. The radar can map water filled fractures. At Site 1 the fractures were mapped to a depth of 4 meters which indicates that they were probably significant features and could control water flow into the tunnel area.

The radar can thus provide useful information on rock masses in this mine. It can see fracture zones, quartz veins, and sulfide veins to distances of 10 meters. This range is too short to provide information throughout the pillars in the mining area, however there are several uses for the system in its present form in safety related areas.

The major fracture zones can control the entry of water into the mine. They also have a determination in the stability of the roof. Thus a regular program of mapping the roof and walls could provide useful information related to the tunnel stability. The fracturing in the pillars in the mine area determine their stability. A radar survey could be used to examine the pillar for fractures near the surface. Finally, in areas where hazards are known to exist, the radar could be used to map ahead of the tunnel entry to determine possible dangerous conditions ahead of the drilling operations.

The radar used in these tests was not built to be a rugged field unit. However, it was able to withstand the cold, damp mine environment. The weakest link in the system is the tape recorder. ENSCO is currently building a new system which should not only eliminate the problems with the current system, but also should be more adaptable for the mine environment.

Finally, the only portion of the mine which proved impossible to survey was the mine roof. The roof of the mine was used to suspend the wires for the trains, therefore it was impossible to hold the antennas near the roof and then move them along the tunnel. Thus in the future, areas which must be surveyed should be kept free of wires and supports so that it is easy to hold the antennas against the wall. If this is done, then it is possible to survey the mine at a rate such that several thousand feet can be surveyed in a day's time.

4. SCHEDULE OF TESTS

The radar surveys were conducted by Dr. James C. Fowler and Mr. Theodore E. Moser of ENSCO, Inc., 5408A Port Royal Road, Springfield, VA 22151. The survey was conducted during the period of 21 to 27 May, 1979. The first and last days were travel days while the other five days were survey days. These were billed as follows:

Travel Days @ $1150/day	$ 2,300. (U.S.)
Survey Days @ $1698/day	$ 8,490.
	$10,790. (U.S.)

ESSO Minerals also paid for all transportation and shipping costs to get the people and equipment to Stewart B.C.

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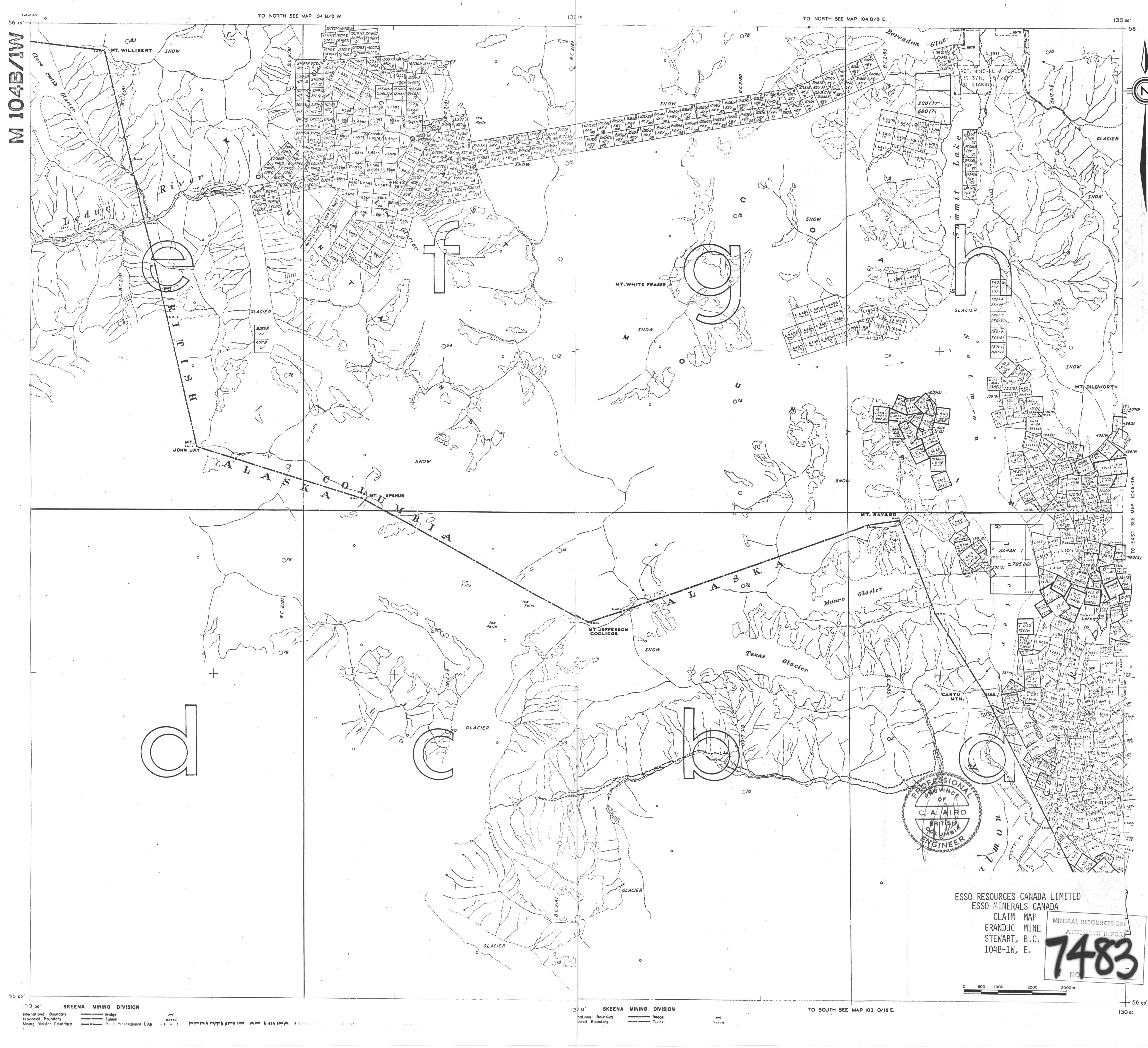
BRITISH COLUMBIA


M 104B/1W
TO NORTH SEE MAP 104 B/8 W.
TO NORTH SEE MAP 104 B/8 E.
TO EAST SEE MAP 104A/4W
TO SOUTH SEE MAP 103 O/16 E.
MT. WILLIBERT
MT. JOHN JAY
MT. UPSHUR
MT. WHITE FRASER
MT. BAYARD
MT. JEFFERSON COOLIDGE
MT. DILSWORTH
CANTU MTN.
Leduc
River
Berendon Glac.
Summit Lake
Munro Glacier
Texas Glacier
GLACIER
SNOW
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Mining Division Boundary
Bridge
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DEPARTMENT OF MINES

GEOLOGY OF TIDE TUNNEL

SECTION

PLAN

LEGEND

10	DIORITE
9	GRANODIORITE
8	DIABASE
SEDIMENTS	
7	ARGILLITE, SILTSTONE
6	MINE SEDIMENTS
VOLCANICS	
5	ANDESITE
4	GREENSCHIST
3	PILLOW LAVA
2	AGGLOMERATE
1	TUFF

SYMBOLS

- FAULT
- CONTACT
- SNOW LINE
- ICE POLES
- STRIKE and DIP

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500 M
SCALE IN FEET

7483

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LOCATION OF RADAR TEST SITES