United States Department of Agriculture
Soil Conservation Service
Northeast NTC
160 East 7th Street
Chester, PA 19013

Subject: Feasibility of using ground-penetrating radar (GPR) to identify hollows in trees; October 24 & 25, 1988

Date: November 3, 1988

To: W. Frank Miller
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File code:430-6

Purpose:

The National Park Service (Olympic National Park) and forestry departments of municipal governments are seeking a fast, nondestructive technique to identify decayed areas in trees. Decayed trees are responsible for large losses of board feet from commercial forests and pose a wind-throw hazard. Decay or rot is caused by fungi. Traditional boring methods used to detect rot are slow and destructive to trees as holes provide entrance points for wood-rotting fungi and insects. In response to a request by Miles T. Hanchett (Director, Quest Northwest, Edmonds, WA), a preliminary study was conducted in Connecticut (see my trip report, dated 31 March 1988). This study represents a more comprehensive investigation. In this study, the effectiveness of GPR to identify and chart the extent of brown rot and hollows in trees was confirmed.

Discussion:

Four trees (water oak (1), sweetgum (2), and Schumard oak (1)) having "catfaces" or visible areas of butt rot were selected. Two to three parallel lines were established on opposing sides of the basal parts of each tree. Observation marks were painted on each trunk at evenly spaced (two foot) intervals along each line from the base to a height of 10 feet. At each mark the diameter of the stem was measured with tape, caliper, and radar.

A study was conducted in the field to evaluate the accuracy of tape, caliper, and radar for determining the diameters at each observation mark. Scatter diagrams plotting the covariation between tape and caliper measurements and between tape and radar measurements are shown in Figure 1 and Figure 2, respectively.

Based on a sample size of 54, the sample correlation coefficient, r, between tape and caliper measurements was 0.96. The sample correlation coefficient between tape and radar measurements was 0.85 and between caliper and radar was 0.82. However, variations exist between all methods, and results are subject to errors and seldom repeatable. The tape and caliper measurements were the most closely correlated. Sixty eight percent of the tape and caliper measurements were within one inch and 93 % within two inches of each other. The tape and radar measurements had a lower correlation coefficient and a higher degree of variation with 46 % within one inch and 76 % within two inches of each other. The lower correlation between the radar imagery and the diameters measured with taper or caliper is caused, in part, by variations in dielectric constants between species and within individual trees (decayed versus non-decayed areas), observation errors (rounding-off measurements, non-perpendicular tape and caliper measurements, etc.), slight spatial discrepancies among measurement sites, and scaling errors.

The selected trees were felled and taken to the Forestry Laboratory, Mississippi State University, where they were again scanned with the 500 Mhz antenna. The correlation between caliper and radar measurements was higher for the felled (0.95) than the non-felled tree (0.82) and reflects the more controlled conditions at the Forestry Laboratory (Figure 3). Eighty-two percent of the radar and caliper measurements were within one inch and 91 % within two inches of each other. The averaged difference between caliper and radar measurements was 0.73 inches (see Tables 1 to 4). It is concluded that the 500 MHz antenna can provide highly accurate measurements through the stems of trees.

TABLE 1

Schumard Oak
(all measurements in inches)

Observation Point	Caliper Measurement	Radar Imagery	Difference
1	19.7	21.0	1.3
2	18.5	18.5	0.0
3	17.2	17.9	0.7
4	17.0	17.0	0.0
5	16.8	15.1	1.7
			x = 0.74

TABLE 2

Sweetgum
(all measurements in inches)

Observation Point	Caliper Measurement	Radar Imagery	Difference
1	15.5	17.0	1.5
2	14.2	15.2	1.0
3	14.6	14.1	0.5
4	13.0	12.9	0.1
5	13.0	12.6	0.4
			x = 0.7

TABLE 3

Water Oak
(all measurements in inches)

Observation Point	Caliper Measurement	Radar Imagery	Difference
1	23.1	22.1	1.0
2	18.5	17.3	1.2
3	16.6	15.1	1.4
4	15.3	15.1	0.2
5	15.7	16.0	0.3
6	14.1	13.5	0.6
			x = 0.8

TABLE 4

Sweetgum
(all measurements in inches)

Observation Point	Caliper Measurement	Radar Imagery	Difference
1	22.4	23.9	1.5
2	17.1	17.6	0.5
3	15.0	16.3	1.3
4	14.6	15.4	0.8
5	14.3	15.7	1.4
6	13.9	14.8	0.9
			x = 1.1

Radar profiles of healthy (A) and decayed (B) trunk portions of sweet gum trees are displayed in Figure 4. In each profile, the 500 MHz antenna was moved along and parallel with the trunk's surface. Reflections from the trunks' surfaces have been labelled (a). In Figure 4A, the interface separating heartwood from sapwood has been identified b). While prominent in this healthy sweet gum, this interface is not apparent in decayed areas and in all species. The identity and extent of decayed areas in the four felled trees were readily discerned from radar profiles. In Figure 4B, areas of brown rot and an open air-filled cavity surround "c". This area extends about 7.6 feet along the butt of the tree.

The GPR accurately delimited knots and areas of incipient and brown rot in the four felled trees. All interpretations and estimates of the extent of hollows and decayed wood were confirmed by sawing the logs on a portable wood meizer saw.

Conclusions:

The ground-penetrating radar can be effectively used to identify and measure the extent of decay or hollow areas in the trunks of trees. Success is dependent on tree species and size, and may vary with the time of the year (dormant versus non-dormant). This application of the GPR needs to be tested further. It would be most advantageous to test the GPR on the trees of interest to the National Park Service.

Enclosed are two complete records of the radar profiles.

With kind regards. "Max"

James A. Doolittle
Soil Specialist (GPR)

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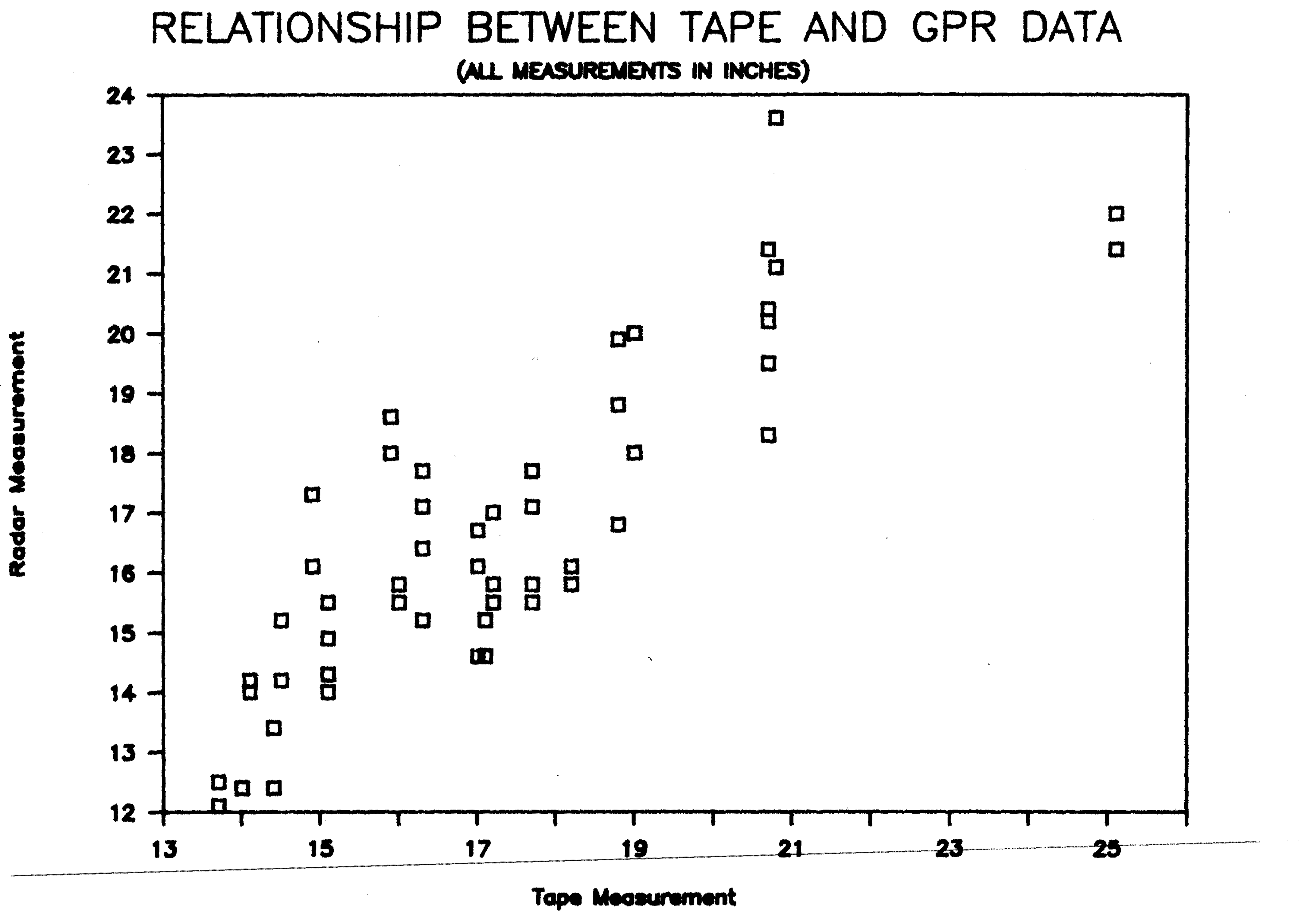
David Jones, State Soil Scientist, SCS, Jackson, MS



RELATIONSHIP BETWEEN TAPE AND GPR DATA
(ALL MEASUREMENTS IN INCHES)
24
23
22
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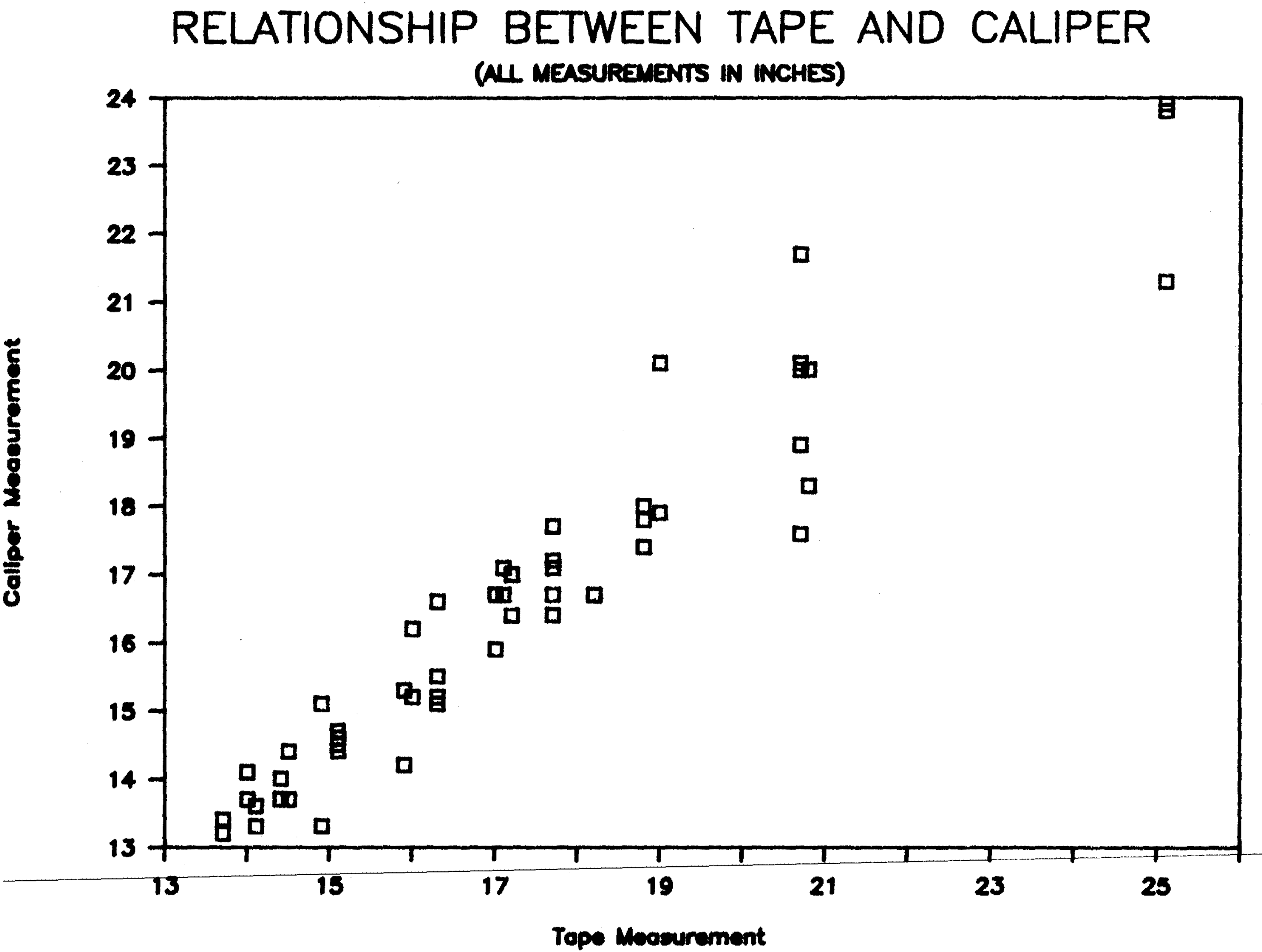
25
Radar Measurement
Tape Measurement


RELATIONSHIP BETWEEN TAPE AND CALIPER
(ALL MEASUREMENTS IN INCHES)
Caliper Measurement
Tape Measurement
13
14
15
16
17
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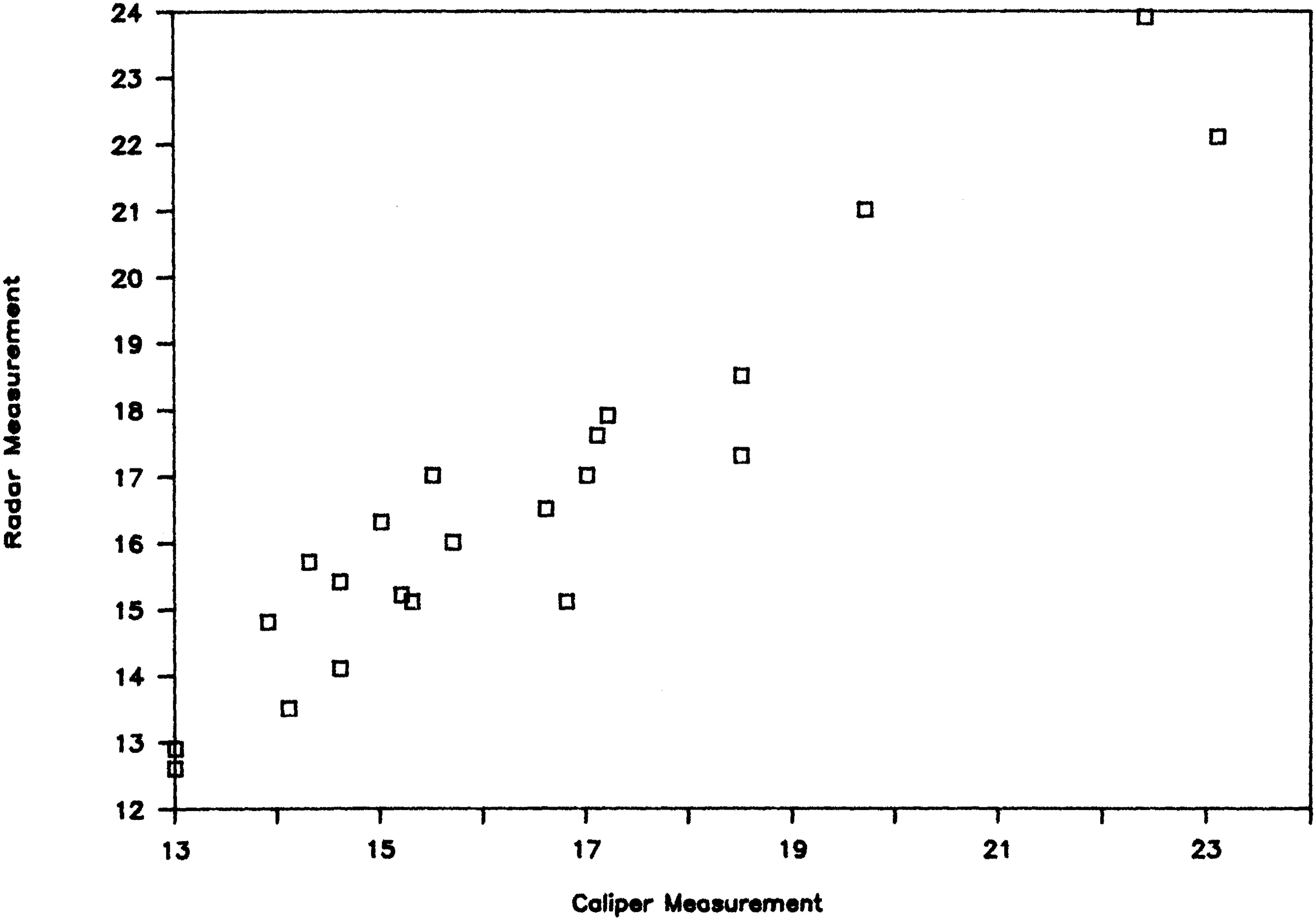
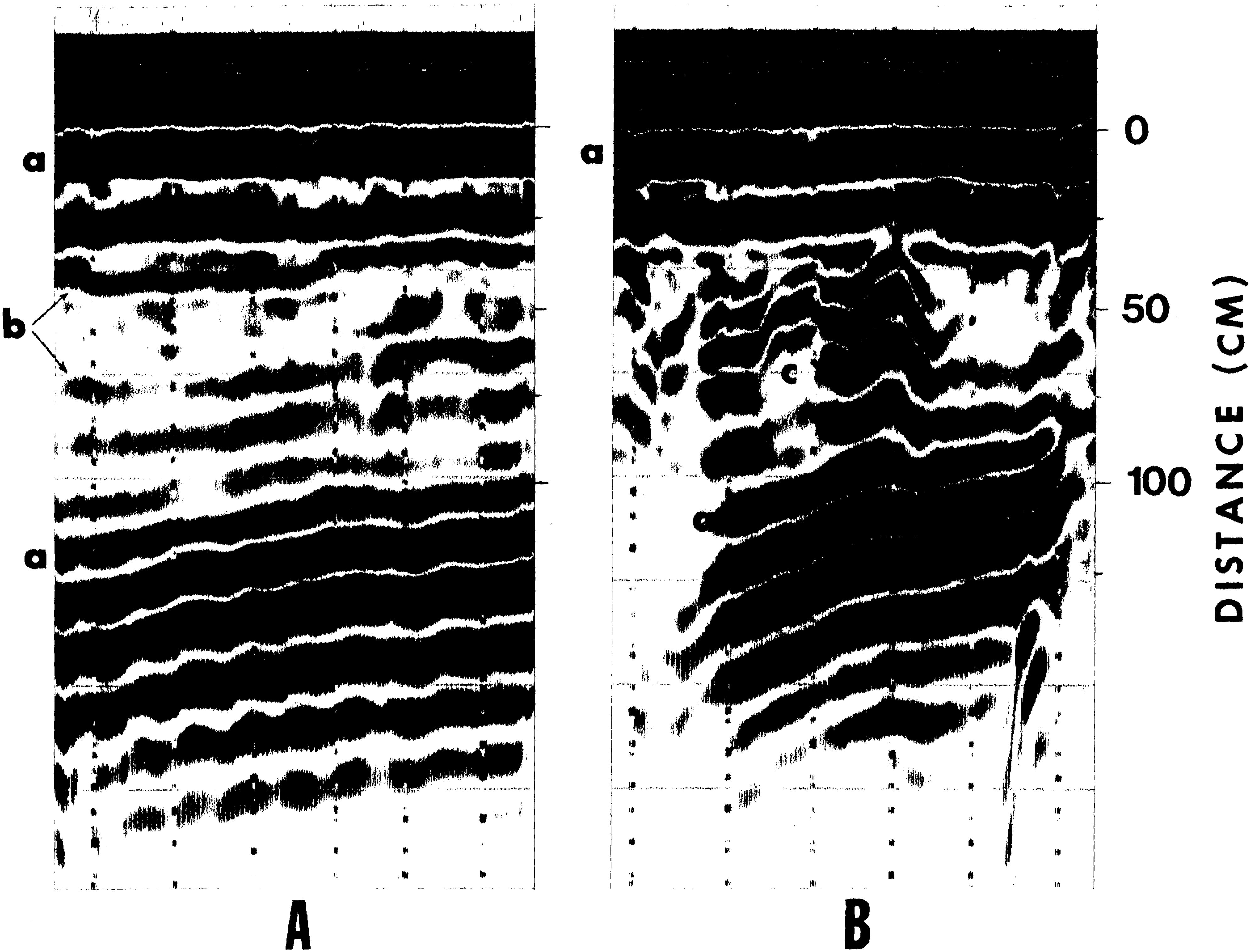
25

RELATIONSHIP BETWEEN CALIPER AND GPR

(ALL MEASUREMENTS IN INCHES)




a
b
a
c
c
0
50
100
DISTANCE (CM)
A
B